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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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NORTHWEST MEDICAL ISOTOPES (NWMI) SUBCOMMITTEE

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OPEN SESSION

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WEDNESDAY

AUGUST 23, 2017

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 8:32 a.m., Margaret Chu, Chair, presiding.

COMMITTEE MEMBERS:

MARGARET CHU, Chair

RONALD G. BALLINGER, Member

DENNIS C. BLEY, Member

CHARLES H. BROWN, JR., Member

WALTER L. KIRCHNER, Member

JOSE MARCH-LEUBA, Member

DANA A. POWERS, Member

JOY REMPE, Member

GORDON R. SKILLMAN, Member

JOHN W. STETKAR, Member

MATTHEW W. SUNSERI, Member

ACRS CONSULTANT:

KORD SMITH

DESIGNATED FEDERAL OFFICIAL:

KATHY WEAVER

ALSO PRESENT:

ALEXANDER ADAMS, JR., NRR

STEVE ALEXANDER, ISL*

JOHN ATCHISON, ISL*

MICHAEL BALAZIK, NRR

DAN BARSS, NMSS

STEWART BLAND, Chesapeake Nuclear Service

MICHAEL CORUM, NWMI

GARY DUNFORD, NWMI

CAROLYN HAASS, NWMI

JIM HAMMELMAN, NMSS

LOUISE LUND, NRR

JAMES MASTERLARK, NMWI*

CLIFF MUNSON, NRO

TY NAQUIN, NMSS

ANNIE RAMIREZ, NMSS

STEVEN REESE, NWMI

SALLY SCHWARZ, Public Participant*

MOLLIE SEMMES, NMSS

APRIL SMITH, NMSS

SAM SWAN, NWMI*

DAVID TIKTINSKY, NMSS

ANDREA D. VEIL, Executive Director, ACRS

*Present via telephone

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P R O C E E D I N G S

8:32 a.m.

CHAIR CHU: This meeting will now come to order. This is the second day of a two-day meeting of the Advisory Committee on Reactor Safeguards, Northwest Medical Isotopes, NWMI Subcommittee.

I'm Margaret Chu, Chairman of the Subcommittee. Members in attendance today are Ron Ballinger, Matt Sunseri, Gordon Skillman, Dana Powers, Jose March-Leuba, Walt Kirchner, Charles Brown, and Joy Rempe.

MEMBER STETKAR: And John. You skipped me.

(Laughter.)

CHAIR CHU: Oh, and John Stetkar.

MEMBER STETKAR: You skipped me yesterday.

CHAIR CHU: Sorry.

(Laughter.)

MEMBER STETKAR: So, it's fine.

CHAIR CHU: I did skip you yesterday.

MEMBER STETKAR: I'm the great void in the --

MEMBER SKILLMAN: She got all the important people.

MEMBER STETKAR: No. She did.

(Laughter.)

CHAIR CHU: Sorry.

MEMBER STETKAR: The transcript will have, you know --

(Laughter.)

CHAIR CHU: We hear a lot of you afterwards.

(Laughter.)

MEMBER STETKAR: Easy, easy.

CHAIR CHU: The purpose of this two-day meeting is for the subcommittee to hear a briefing from representative from NWMI regarding their construction permit application for a radio isotope production facility in the city of Columbia, Missouri for production of Moly-99.

We also expect to hear from the NRC staff regarding the review of this application and the NRC staff's safety evaluation report.

The following NWMI construction permit application preliminary safety analysis report, PSAR Chapter and the associated NRC staff's safety evaluation reports are scheduled for discussion today as noted in the agenda, which is Chapter 13, accident analysis and the integrated safety analysis, ISA summary.

This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Rules for the conduct of and participation in the meeting have been established in the Federal Register as part of the notice for this meeting.

Kathy Weaver is the Designated Federal Official for this meeting. Portions of the meeting will be closed to the public to protect information proprietary to NWMI or its vendors.

We have designated a portion of the afternoon session to discuss proprietary information, toward the end of the meeting as shown on the agenda. And this session will be closed to the public.

A transcript of the meeting is being kept. Therefore it is requested that all speakers first identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

During the open portions of this meeting, a public bridge line will be open on mute so that both individuals may listen in. At the appropriate time later in the meeting, we'll have an opportunity for public comments on the bridge line and from members of the public in attendance.

During the closed portion of the meeting, the public bridge line will be closed. The staff has asked to have an open line during the meeting so that certain NRC contractor and staff who are a part of the safety review can respond if necessary to ACRS members' questions.

We ask that you keep this line on mute unless speaking to avoid disruption. We will not proceed with the meeting.

And before I do that, I -- we have one more member attending. It is Dennis Bley.

We will not proceed --

MEMBER BLEY: It's shaping.

(Laughter.)

CHAIR CHU: I will now call up Louise Lund, the Director of Division of Policy and Rule Making in the Office of Nuclear Reactor Regulation to open the presentations today.

MS. LUND: Yes. And thank you Dr. Chu and good morning everyone. And I think we had a lot of good and productive dialog yesterday.

And we look forward to continuing with that today for those sections that are on the agenda for today. And with that said, I'm going to turn the presentation over to Carolyn Haass of Northwest Medical Isotopes.

MS. HAASS: So I just want to thank everyone for letting us come again. Today is going to be the most fun filled day you've had yet so far with us.

You know, we're getting into the fun part. And so we're going to talk about our ISA methodology and our PHA and go into Chapter 13, the safety analysis.

And I'm going to turn it over to Mike Corum right now who is our lead on the ISA. And then over to Gary Dunford on Chapter 13, what we'll go through later this morning.

MEMBER REMPE: Carolyn?

MS. HAASS: Yes?

MEMBER REMPE: Yesterday when we talked, and this was in the open session and then there was some additional dialog about it in the closed session. But, it really affects how I view the ISA and Chapter 11 and Chapter 13.

And so I went back through Chapter 13 last night. And on the very first page, it says your facility is being designed to have a nominal operational processing capability on a batch per week of up to X targets from the University of Missouri Research Reactor for up to 52 weeks per year. And up to -- and eight targets from the Oregon State University.

And X is bigger than eight. Which was said in the public session yesterday that was used for the Chapter 11 dose analysis.

And what is it you're trying to get from the NRCs for the -- I mean, it seems to me if you're doing X, it seems like when you do like the maximum hazard analysis, a credible whatever it is hazard, you should do indeed X. Which is what you did.

So I'm still puzzled why in the dose assessment for Chapter 20 you only went to eight. And I think I was told well, we're not really sure we're going to go up to 12.

Or it's only going to be if there's a demand. But when you go for the license for it, it seems like you've got to say what you're going to have for the maximum license.

And so could you explain that again to me a little bit?

MS. HAASS: Yes. You can go ahead.

MR. REESE: So, I can -- all right. So the logic behind how much we're running at any given time, the business side of the house setting that aside, just in safety space, there's a certain number of targets coming from OSU. All right? And there's a certain number of targets coming from MURR.

MEMBER REMPE: Um-hum.

MR. REESE: So nominally, the inventory in both of those hosts a radiation is nominally about the same. But that inventory is much less coming from OSU because of the decay associated with transportation.

MEMBER REMPE: Right. I get it.

MR. REESE: Yes. So the difference we have is between let's say the low core number A and the higher number B at MURR.

MEMBER REMPE: Right.

MR. REESE: So, we look at it two different ways. When we look at it in terms of looking at the inventory that moves through the facility at any one time over an extended period of time, we look at that in terms of B, number of targets.

MEMBER REMPE: Okay.

MR. REESE: Because that would result in the highest inventory in the system if we ran like that.

MEMBER REMPE: Right.

MR. REESE: However, in accident space that Gary and Mike are going to be talking about today, we're still the highest inventory source terms that serves as the accent source term for many situations is that first batch of half of A comes from MURR.

MEMBER REMPE: Okay. Okay. I understand that.

MR. REESE: Okay.

MEMBER REMPE: But some of the analysis in the -- you're talking about how many targets are in a dissolution thing.

MR. REESE: Yes.

MEMBER REMPE: I think you can only do half of something.

MR. REESE: That's right. That's fine. Yes.

MEMBER REMPE: But then on Chapter 11 you went to two. Or I don't -- I mean, you actually said eight yesterday is what you used.

MR. REESE: Okay.

MEMBER REMPE: And to me, that's more than what you have in the dissolution. So that's basically, I think you meant to put the maximum amount in the facility in Chapter 11. And you did eight. And that's not from the maximum amount that you might have at MURR.

Now, you're not sure whether you really will need the maximum amount from MURR because it's a demand-based thing. But, if you're going for a license, you need to say the maximum amount that will be there.

And that's where I'm kind of puzzled. Why you didn't on Chapter 11 and you did later on with your maximum credible hazard analysis.

And that's where I was confused.

MR. DUNFORD: So this is Gary Dunford. Yes, that analysis, and I think I said it in -- maybe it was in the closed session.

MEMBER REMPE: Yes. At the very end. You tried to tell me.

MR. DUNFORD: The eight for the comply will be redone as part of the FSAR. Substituting in a larger value and a more consistent operating.

Because that doesn't actually factor in the 30 targets, which would actually lower it for those weeks a little bit. Not much.

So, we will redo it as part of the operating license. The value still will be less than ten. Our initial assessment is the value will be six or something like that.

MEMBER REMPE: But okay. So --

MR. DUNFORD: As a normal release.

MEMBER REMPE: For a normal one. But what if you decide the demand is hotter then hell. And you're going to try and -- you know, you're going to try and get up to 12 a week.

Don't you think -- I mean, that's what -- what's going to happen if you decide you need more? Are you going to come back into the NRC and say well, we didn't actually, you know, eight or whatever you pick isn't the full 12.

Are you going to have to come back to the NRC?

MR. DUNFORD: Well, our requirement is -- well, I guess I'll let Steve answer that, the longer term acts.

The near term thing is the limit is ten. We have to stay below ten.

MEMBER REMPE: So you could come back. So this thing at the beginning of Chapter 13 that says you want to have a nominal capability up to some number that's bigger than ten, --

MR. REESE: Oh, wait, wait, wait. You guys are mixing -- you guys are mixing things. You mean ten as in gaseous releases?

MR. DUNFORD: It says normal gaseous release, 10 CFR 20.

MEMBER REMPE: It was a liquid I thought.

MR. REESE: Well, so the ten is the constraint in the gaseous releases. He's not talking targets. He's talking about those.

MEMBER REMPE: Yes. It is. But shouldn't it be based on the maximum amount that you're going to use? Why is it not more than --

MR. REESE: And I think that's what Gary was saying yesterday. Is that they'll redo the comply codes for the higher amount.

MEMBER REMPE: So you will go up to -- and I think you just said the magic number of more than eight.

MR. REESE: Yes. Yes.

MEMBER REMPE: You did. So, now you go get -- but, I mean, you'll go up to the number that's the maximum. And so Chapter 11 might -- the value might be increased more than eight? Which is what we saw yesterday.

MR. REESE: And that's what Gary is saying. Yes. Right.

MEMBER REMPE: Okay. And I think if you were going to put a number that's bigger than ten that you're going to have a nominal operational processing capability of up to X targets, I think you've got to put that number in Chapter 11. Nothing less than that.

Or you need -- whatever it is you want to put in your mass, --

MR. REESE: Yes.

MEMBER REMPE: You need to put it into Chapter 11. Okay. That's where I'm coming from.

MR. REESE: Yes. I agree with that. Yes, yes.

MEMBER REMPE: So, there needs to be consistency somewhere.

MR. REESE: Yes.

MEMBER REMPE: Okay. That's what I was trying to get to yesterday and I didn't get that.

MR. REESE: Yes.

MEMBER REMPE: Okay. Sorry for all that.

MR. CORUM: Good morning. I'm Mike Corum and I'll be giving the presentation on the ISA. But I'll encourage any of the NWMI folks to jump in when they feel necessary.

So, the ISA is allowed to be used as a methodology from NUREG-1537, the ISA methodology is in 10 CFR Part 70. And go ahead to the next slide, please. Yes.

And that allows us to do the radiological and chemical consequence and likelihood use that criteria that's based in the performance requirements of 10 CFR 70.61.

And which allows us to create items relied on for safety and establish management measures as an acceptable way of demonstrating adequate safety of the facility.

So, the ISA is a systematic examination. And I hope we convey that today of how systematically that really is.

And we go through the facility's processes, equipment, and structures, and personnel activities in a systematic way to try to capture all of the relevant hazards that could result in an unacceptable consequence.

And the criticality safety evaluations that we went through yesterday are a subset of that ISA process. And feed into the -- into the ISA.

So on slide three we've got a, I guess, a diagram of the process involved with the ISA. And I think it's probably good to go through this in detail. And it will kind of cover a number of the other slides that come after this, so.

And we talked about this a little bit yesterday afternoon, the upfront portion of it. The planning portion is shown on the far left-hand side.

And that's where the process designers, process engineers put together the PNIDs and the process flow diagrams. And get those out to the members of the ISA team so that they can conduct their preliminary investigations and preliminary, you know, hazards and consequence.

To get those thoughts in their mind before they go into -- into the PHA. And from criticality safety and fire protection standpoint, we can do some preliminary calculations to give us an idea of what those back beam parameters are that we're going to propose during the PHA process.

So, the center portion of the diag -- or the second portion of the diagram goes through the activities of the ISA team.

So, and it starts out with initiating the process by collecting all the preliminary data. You'll have a PHA lead that is in charge of getting all that data out to the members of the ISA team to review prior to the PHA.

And then we just -- we go into the PHA. And in the PHA, we're going systematically through the process, through everything that we're going to do in the facility.

And basically come up with the hazards that we think should be addressed, or the hazards that are present in those activities. And we use a number of tools in PHA space with haz-op, what if, event free -- event tree/fall tree.

Those usually come later in the process when it's a little bit more mature. But, primarily what if and haz-ops are the type of tools that we use during the PHA process.

And what we're doing there after we come out of the PHA then is we're categorizing the events for likelihood and consequence and risk. And that's kind of our screening process that we use to see whether we're going to go into QRA space or the need for IROFS.

So, then when we determine whether we've got intermediate or high consequence risk. And if we do, then we're going to perform the QRAs to quantitatively evaluate the risk and identify any IROFS.

Now that's the process for the non-criticality safety side. For the criticality safety side, criticality is, by definition, a high consequence event.

So, we already know that we're going to have to do the analysis, the evaluations, as well as crit-safety analysis to meet the performance criteria. So the other radiological and chemical, we have that opportunity to do the QRAs and identify the IROFS at this point.

So, coming out of the QRAs, if we still

have the high or intermediate risk events, we're going to identify accident sequences and develop IROFS. And the basis for each in a complete QRF.

And from that then we develop the PSAR and the ISA summary and eventually the tech specs.

MEMBER BLEY: Michael?

MR. CORUM: Yes?

MEMBER BLEY: I just skimmed through your slides. I'm not sure you actually talk -- if you have a slide where you're going to talk about the place where you define an event is not credible in the ISA with the three criteria on external event, process deviation and the convincing argument that it's not possible, I'll wait.

But if you don't intend to go through those three, I'm going to ask you a question.

MR. CORUM: I'm not sure if we've got that --

MEMBER BLEY: I didn't see it.

MR. CORUM: Specifically in here. But yes. Those -- there are three specific criteria in NUREG-1520.

MEMBER BLEY: Okay. Well, the first one is pretty clear to me.

MR. CORUM: It is. Very clear.

MEMBER BLEY: Which is the external event is a frequency of less than ten to the minus six.

MR. CORUM: Correct.

MEMBER BLEY: The second one, the process deviation consists of a sequence of many unlikely, many I'm not sure of what that means. Unlikely events or errors, though you've defined that, for which there is no reason or motive.

And that one troubles me a little. Because that's pretty tricky. We often don't see the reason or motive ahead of time after we look at a bad event.

If we looked at it correctly, not just from the outside, but if we see what the operators were doing in the midst of it, --

MR. CORUM: Right.

MEMBER BLEY: We often see there was a logic to what they did. And it takes a fair amount of work and care to identify those ahead of time.

How are you dealing with that?

MR. CORUM: And primarily you kind of hit it on the head there. This particular -- I guess this particular item is generally used in -- when you're dealing with administrative controls.

And --

MEMBER BLEY: So you've lim -- have you

limited the admin controls?

MR. CORUM: Not limited. But that's where I've seen the application of this most often, is in the use of admin controls.

The clincher in this is if you look at the very last sentence. And it says, of course this can -- has never happened in any fuel cycle facility that's in operation or --

MEMBER BLEY: But the next thing that happens bad may have never happened in any other facility.

MR. CORUM: You're right.

MEMBER BLEY: So, this idea that there's no reason or motive, you really have to kind of get inside. And you don't even have the procedures.

Well, you do have procedures. We haven't seen them yet.

MR. CORUM: Right.

MEMBER BLEY: But you have to get inside the procedures. And what could go wrong and how could I get in this spot where all of a sudden, it's not crazy to open this valve and shut that one or something --

MR. CORUM: Right. Right.

MEMBER BLEY: Because of the local situation.

MR. CORUM: Yes. And I have never used this. Nor would I ever recommend any of my safety engineers use this as a reason for a not credible arguments.

MEMBER BLEY: Okay. But even -- even if you keep it and go, if you incorporate it in the ISA, you have to be really careful on that looking. Or otherwise you come up thinking things are almost impossible when maybe they're not.

MR. CORUM: You do. And in our lower level documents in our crit-safety manuals that we have put together for guidance on how to do criticality safety in this facility, that is not one of the three that we've chosen to use as a -- as a sign of a not credible event.

So, we don't use that one at all.

MEMBER BLEY: Well, as you go through the rest, I'll be watching for that kind of thing. And I haven't made it through everything yet. So, I don't know if I have a concern there or not.

MR. CORUM: Right.

MEMBER BLEY: The third one is kind of clear. But it says a convincing argument exists that given physical laws, process deviations are not possible.

That's pretty good if we can do that. Or, are extremely unlikely.

MR. CORUM: Right.

MEMBER BLEY: We haven't identified that. But given your table, I guess that means you think it's less than ten to the minus six? Or what does that mean?

MR. CORUM: To me that means it's physically not possible.

MEMBER BLEY: So you don't -- you don't dwell on this ten to the -- you don't dwell on this extremely unlikely. It's not possible.

MR. CORUM: Right. It's not possible. That's the way we look at it.

MEMBER BLEY: And is that the philosophy used by everybody doing this work?

MR. CORUM: In -- for the NWMI work.

MEMBER BLEY: I'm much more comfortable if that's what you're doing.

MR. CORUM: Yes. Yes, that would be like a solution running up hill without any motive force whatsoever.

MEMBER BLEY: Yes. Okay.

MR. CORUM: So that's physically impossible.

MEMBER BLEY: So you're hanging onto the not physically possible part of that.

MR. CORUM: Correct. Correct.

MEMBER BLEY: That makes me happy. I'm sorry, John, I cut you off.

MR. CORUM: That's the way we look at that.

MEMBER STETKAR: No. That's okay. I don't know when or in what detail to discuss comments. I think most of them are probably, I don't want to waste the subcommittee's time or your time with a lot of details.

And I suspect a lot of the ones that I do want to mention are better in the proprietary section. But, to tee off a little bit of what Dennis said, and Mike, what you said, I wanted to get on the record here.

Not unexpectedly, I went through the whole PHA. Every line item. And all of the QRAs. Every word.

You carefully said that you would never use those unexpected multiple whatevers in a criticality analysis. I didn't find any entries in the PHA screened out, I'll use that term, in terms of criticality safety based on that argument.

I did find some that were screened out on a radiological dose perspective spills. Not criticality, spills or upsets where the argument was made that it would require a lot of unlikely personnel errors.

And therefore it was considered highly unlikely or not critical or something just qualitatively. So, there are -- I'll just say, there are some in there from the radiological dose consequence perspective that were screened out.

I don't want to give you details. Because like I said, they were probably considered proprietary. We can discuss them in the proprietary session if you want, a couple of examples.

But, just to put it on the record that that criterion apparently was used by some people looking at the radiological dose consequence issues.

MR. CORUM: Okay. Okay. Yes. We'll look at that in the final phase, so. But yes, as I said before, I would not recommend using that as the basis for a not credible argument.

Unless we have a quantitative analysis that we've done that we can show that because of all of those upsets that we get to the frequency criteria that's actually in item one rather then item two, so.

All right. I think we can go to the next slide and see what I've already covered on this one.

Yes. I think I covered most of slide four when we were going through the slide three.

So let's go to slide five. And that's where we start looking at the consequence severity categories that are in -- derived from 70.61.

So, the high consequence event is defined to both the workers and the offsite public. They should look very familiar because they came straight out of the regulations or the guidance documents.

Intermediate consequences are also broken down that way. As well as low consequence.

For the consequence categories, we assign a qualitative value to high consequence, intermediate consequence, and low consequence categories. And that goes in three, two, one, in order of -- from high consequence to low consequence.

So that becomes important when we start looking at the -- at the risk, qualitative risk analysis that we do later on in the ISA.

So on slide six then we look at the likelihood categories. And there we've defined not unlikely, unlikely and highly unlikely. And those likelihood categories are three, two, one, going from not unlikely up too highly unlikely.

And those event frequency limits are also shown in that table that we deal with.

MEMBER SKILLMAN: Michael, where does those event frequencies come from, please?

MR. CORUM: Those are from 1520. NUREG-1520.

MEMBER SKILLMAN: 1520?

MR. CORUM: The guidance in NUREG-1520.

MEMBER SKILLMAN: Thank you.

(Off microphone comment.)

MR. CORUM: Right. Right, yes. And 1513 as well. So we've looked at some of the qualitative likelihood category guidelines that we use at NWMI. And those are shown in the lower table.

You can see we have a lot of category threes. A lot of them are human. Some of them are external-event induced as well.

The only highly unlikely category that we have are natural phenomena such as tsunamis, volcanoes and asteroids for the RPF. So, we don't really consider anything right off the bat being highly unlikely. Or fit into that highly unlikely category.

MEMBER STETKAR: But again, that's not quite true.

MR. CORUM: Okay. Got you. Understood. So then the likelihood of occurrence for each accident scenario is based on the frequency of the initiating events, the historic record of occurrence with similar systems, expert engineering judgement, and assessment of the number type independence and observed failure history of the IROFS.

So the risk matrix is shown down at the bottom of this table. And that's where you take the event that you're considering, look at its consequence category.

And then look at the likelihood of occurrence. And figure out where you need to fall under that risk matrix to be acceptable. And all the acceptability is shown in the green. The unacceptable categories are shown in the red there.

So, during the ISA process, at the end when we come to risk categorization, we have to show all high consequence events that had a risk index of three or less. And intermediate consequences have to be a four or a two. And the low consequence can be one, two, or three.

And those risk indexes are found by multiplying the consequence category by the likelihood category in each column. So, column and row.

So for our bounding evaluations we've looked at a worse case approach using a few bounding evaluations that we identify through either calculations.

And those are source term and radiation doses, studies of representative accidents, a bounding release calculation that we've used to model the facility releases that might affect the public, reference to nationally recognized safety organization, and using approved methods for evaluation of natural and man-made phenomena. And comparison to the design basis.

So, the initial hazards that we identified by preliminary reviews included the high radiation dose to the workers and public from irradiated target material during processing, high radiation dose due to accidental nuclear criticality, the toxic uptake of licensed material by both workers and the -- or the public during processing or accidents, fires and explosions associated with chemical reactions, and use of combustible materials and flammable gasses, chemical exposures associated with the chemicals that we're using in the processing of the irradiated target material, and external events both natural and manmade that could impact the RPF operations.

MEMBER STETKAR: Mike, again on --

MR. CORUM: Sure.

MEMBER STETKAR: This is sort of a high level general. The one up from the bottom about chemical hazards.

As I looked at the analysis, there seems to be a pretty comprehensive evaluation of chemical and radiological exposures to workers. In other words that there might be an acid that also has some radioisotopes dissolved in it.

A couple of the evaluations looked solely at chemical exposures in parts of the process where in theory all the radiological material has been stripped out prior to that. And a couple were retained.

Several though of the PHA evaluations said well, this would only be an exposure to chemicals which is a typical industrial hazard. It's screened out.

So I found what seemed to be, depending on what part of the process stream the way the PHA is organized, perhaps a disconnect between whoever was doing the analysis, and I don't know whether a single pers -- you know, I know there were teams that looked at each part of the process. And you described those teams.

There seemed to be a bit of disconnect on how to retain purely chemical hazards without any radiological dose consequences. Because as I said, I know in one part of the process, a couple of sequences were retained for further evaluation.

You'll get to the CS abbreviation later. But in other -- in several other parts they were just simply screened out as saying this is a typical industrial accident. You know, no consequence without any other basis.

So, I -- my basic question was, are you going to revisit those for the final? Is there going to be another final hazards analysis?

MR. CORUM: Yes. There will be another --

MEMBER STETKAR: And are you going to visit those? I mean, that was one of the sort of bigger gaps that I -- that I thought might exit.

But I don't know the actual hazard.

MR. CORUM: Yes. We will go through this complete process for the final design phase again. So we will revisit everything again.

And it could change based on the final design. But, -- and we can definitely, you know, take a different look at this.

MEMBER STETKAR: If you want an example, I mean, we can talk about them in the closed session.

MR. CORUM: Okay.

MEMBER STETKAR: Because I mean, I don't want to -- but it was one area where it --

MR. CORUM: Where it was a disconnect.

MEMBER STETKAR: In fact it was the only area that I seemed to see a kind of philosophical disconnect between looking at some parts of the process -- of the whole.

MR. CORUM: Okay.

MEMBER STETKAR: The whole facility. From evaluation to evaluation across the eight or however many there are.

MR. CORUM: Okay. Yes, I do know that we had one QRA that is specifically dedicated to chemical hazards.

MEMBER STETKAR: There is. And that's for the couple, I don't know -- remember whether it is two or three or four that were retained.

MR. CORUM: Yes.

MEMBER STETKAR: But only from one part of the entire facility process.

MR. CORUM: Right.

MEMBER STETKAR: And in many other cases, upfront. There was never a sequence that was flagged for further evaluation because the generic rationale was, this is a typical industrial accident. Does not involve any radiological consequences.

(Off microphone comment.)

MR. CORUM: Okay. Gary said --

(Laughter.)

MR. CORUM: That those were probably initiating events that led to accidents that were considered industrial accidents. And that they viewed those as standard industrial controls would apply to those rather then IROFS.

So, that was -- that may have been some of the logic used to screen those out. But we will definitely take a look at that.

MEMBER STETKAR: There were some like --

MR. CORUM: Biohazards and that stuff.

MEMBER STETKAR: Like a crane dropping -- well, the crane is a bad example, because you did evaluate cranes.

There were a few that were like, you know, a ladder fell over on my arm or something. That's not a specific example.

But those types of industrial accidents. These -- the ones that I was hanging up on were more of the chemical spills or leaks or sprays or, you know, that kind of stuff.

MR. CORUM: Okay. If we can go to slide

ten. So looking at the accident initiating events, we designated initials for each area that we were investigating, criticality, fire explosion, radiological and so forth, so that we could identify those in the -- during the PHA process.

And that's all this slide is trying to convey there.

MEMBER STETKAR: Mike, again in terms of open session, I know you looked at loss of electrical power. And that's discussed in Chapter 13.

What I did not see anywhere, are what I would call facility -- an evaluation of the facility wide effects from failures of support systems.

And it's a general category. But in particular, chilled water, compressed air, ventilation, steam, DC power.

You evaluate those things on an item by item basis. If I lose cooling to this tank, --

MR. CORUM: Um-hum.

MEMBER STETKAR: This is the consequence from that particular tank. There are arguments saying, well if I lose electric power, I'm going to lose all of that stuff.

What we've found often in the risk assessment business is that losses of support systems with electric power available can oftentimes create situations that aren't necessarily obvious. Especially when you look at the integrated effects across the entire facility.

How do control systems respond to open or closed valves or change levels or start or stop pumps, or do whatever your control systems do, given loss of cooling, given an overheating condition because I lost ventilation or I lost cooling for ventilation. Those types of things.

And I didn't -- it's not clear to me that the item by item individual evaluations will capture the facility wide effects from those support system failures.

And there's certainly -- I can tell you they're certainly not captured by saying, I lose all electric power and everything fails to the way it's supposed to fail given no electric power. You will not find them that way.

MR. CORUM: Yes.

MEMBER STETKAR: So how are you going to address that? That's one of the problems that we've had, quite frankly, with this ISA process.

Is that it tends to be very much of the individual item failure modes and effect's analysis focus rather then an integrated facility evaluation.

MR. CORUM: Right. Yes. And I think you're --

MEMBER STETKAR: How and where are you going to look at that? That's my basic question.

MR. CORUM: Well, and we do that in criticality safety space with common mode failure. Where we evaluate the common mode failure.

And I think that's where we're going here with the overall facility. Is you have to look at common mode failure as well.

It interfaces with --

MEMBER STETKAR: Right. It depends on what you want to talk later about. What your concept of common mode failure is. But that general concept is what I'm trying to get to.

I keep using the term integrated facility wide effects from losses of what I call support systems. Loss of, you know, each of the four chilled water systems.

MR. CORUM: Right.

MEMBER STETKAR: Well, actual water systems I think there are. Loss of ventilation perhaps. Loss of, you know, what's the entire facility wide effect from losing compressed air.

MR. CORUM: Right.

MEMBER STETKAR: those types of things. Loss of DC power can happen.

MR. CORUM: Correct. Right.

MEMBER KIRCHNER: And I want to mention that -- jumping in with John. To first order at this point where you are in the design of the facility, what I've seen is reasonably comprehensive.

But it does beg the question of when you have a final design interfacing systems is -- or I'm not sure how to say it. The things that are in the interstices of taking a look at your design at this point, which isn't finalized, would be very useful for the FSAR phase.

MR. CORUM: Yes.

MEMBER KIRCHNER: You can have much more detail to deal with.

MR. CORUM: Right. Yes, during the final design phase when we're going through the final PHA, that is an opportunity to actually affect the final design.

And I think that a common mode failure is a good point. We need to incorporate that going forward into the PHA process for the final design.

MEMBER SKILLMAN: I'd like to join this

conversation and bring you back to slide five for a minute, please.

It strikes me that maybe the way to get at what John's talking about and what Walt's talking about, and what I raised yesterday about us ventilation, is to identify what combinations of systems can cause the events that are in your third column there?

Kind of like a steam line break. So you know, steam is supposed to be clean. And it's not really a primary coolant. And it's just a medium in order to generate momentum for the -- or energy for the turbine.

But in reality under the right circumstances, the steam becomes your -- your leader in your radiological event if you have primary or secondary leakage.

In this case, what has struck me right from the beginning is, I think the most vulnerable system you have is your ventilation system. Because you're depending on that to evacuate the entire facility and to keep all of the areas at a radiological level that is safe for the workers and safe for the public.

So, it just strikes me that maybe there is a hierarchy between DC electrical, compressed air and ventilation that sets up that unforgiving set of circumstances where you really do end up with a radiological event that causes either the ventilation system or the combination of ventilation plus DC and maybe compressed air to create a high consequence event.

It's almost obscure because of the way you are approaching the items on slide ten. Which are criticality, loss of electric power, and so on.

What I'm suggesting is there probably is a -- not just a systematic approach, but a systems approach to addressing the high consequence, intermediate consequence, and low consequence events based on the requirements that are out of 70.61.

At least that's kind of how I'm thinking about this. Instead of having the stylized or very laser like focus on the initiating events, perhaps there is a higher vision of this that begins with, what are the systems that are essential for protecting the public and the workers from those circumstances that are pointed out in 70.61?

It seems to me that the top tier of that is going to be protecting your ventilation system and whatever it takes to keep your ventilation system functioning in accordance with its design to prevent that from occurring.

CHAIR CHU: I agree with what Dick said.

We used to do that kind of stuff at Sandia Labs. Is basically look at the worst thing that could happen.

And in addition to the bottoms up approach, we also say, what are the necessary conditions for that thing to happen? Okay?

And then you kind of figure out how to take out a couple of the necessary conditions. So that worse things won't happen.

So, kind of give you a different perspective at the highest vulnerability part.

MEMBER STETKAR: Let me interject something here. Just I have to do this on the record.

A risk assessment process says what can happen. It doesn't say what's the worst possible thing that can happen from consequences.

It doesn't say what's the most likely thing that can happen in terms of frequency. It says what can happen.

Given that happens, how likely is it? And what are the consequences? So we don't presume that ventilation is the worst.

We don't look at the worst possible consequences from anything that could possibly happen. We ask ourselves systematically what can happen?

Can I lose the main process chilled water system with everything else available? The answer to that question is yes. That's something that can happen.

And I can lose any one of the three subset process chilled water systems by itself. I can lose different parts of ventilation due to different reasons.

I can lose different chunks of DC power due to different reasons. I can lose different chunks of AC power. And I'm intentionally using these terms to stay away from anything that's very specific.

But it's that systematic process of looking at what can happen without any presumptions about that I want to look at the worst stuff first because I know it's the worst.

And then saying, well now that I've identified something that can happen, how likely is it? What is its frequency?

And if it does happen, what's its facility wide consequences? What valves go open? What valves go closed? What fans go off?

What -- you know, how do the control systems respond to whatever it is? All that kind of stuff.

And I think you have to be careful about doing that. Because there is this notion that we know what the worst thing is. And as long as we protect ourselves against the worst thing, we're fine.

Because we found in many cases that the -- in terms of risk, what I call intermediate frequency/intermediate consequence stuff, can bite you more than the high consequence/low frequency, or you know, high frequency/low consequence stuff.

Hopefully the high frequency/low consequence stuff is indeed just that. It's low consequences.

So just be care -- I had to say that on the record. Just to kind of make sure that you didn't think there was unanim -- we were unanimous in terms of saying well, just look at what we think the worst stuff is and take a look at that.

MR. CORUM: All right. So, we're on slide 11 now. And this is just a crosswalk of the accident initiating events versus the top-level sequence categories, and the effects in each, I guess, in each category.

So, for a criticality accident, we would expect, of course, criticality to be affected as well as the -- some fire and explosion could be effected. And the natural phenomena hazards could definitely affect the criticality accident.

Loss of electrical power, we've got that categorized. It was radiological and natural phenomena. External events, criticality safety, fire, man-made, natural and then chemical as well.

The critical equipment malfunction that hits all of them except for natural. Operator error, criticality safety, radiological, man-made and chemical.

Facility fire is the fire and radiological primarily. And then any other event that potentially related to facility operations. Criticality, radiological and man-made.

MEMBER BLEY: So two things about this. Is this an a priori kind of look on your expectations? Or is this a tabulation of what you found after you did your analysis?

MR. CORUM: This is the latter. Yes. A tabulation of what we found after we went through each of them.

MEMBER BLEY: Okay. Then that kind of helps. Because the last line was really bothering me, any other event.

MR. CORUM: Oh.

MEMBER BLEY: And that can only go to three things. But that's just because that's what came out of your analysis. Okay.

MEMBER STETKAR: This is my impression is you went through the whole PHA.

MR. CORUM: Correct.

MEMBER STETKAR: And you came up with, you know, a huge laundry list of stuff --

MR. CORUM: Pages and pages.

MEMBER STETKAR: Pages and -- many, many pages.

MR. CORUM: Many, many pages. Yes. Yes. A lot of line items in there.

MEMBER STETKAR: Right. And then you went back because apparently the staff wants you to do this. You needed to show how all of that folded into this discrete set of things --

MR. CORUM: Categories.

MEMBER STETKAR: In NUREG-1537. So you had to check off some boxes somehow. Which is --

MR. CORUM: Correct. Correct.

MEMBER STETKAR: You needed to show that all of the boxes were check off somewhere and somehow.

MR. CORUM: Somewhere and somehow. Yes.

MEMBER STETKAR: Okay.

MEMBER BLEY: I want to go back to something John talked to you about just to get something on the table for him.

He's mentioned several times about that a partial loss of power with power to some things and not to others and funny ways can sometimes be more significant then a complete loss. Because you've designed against a complete loss. You got that worked in.

I don't know if all your dampers and valves are going to be -- if they're powered are going to be powered by electricity. Or if you're going to go to instrument air or something like that.

If you go to instrument air, it can be even more bazaar if you get -- if you lose all air pressure, you've designed for that.

MR. CORUM: Right.

MEMBER BLEY: But if you get some dirt in there or some moisture, or something happens, all of a sudden weird stuff starts happening all over. And you don't even tie it to instrument air.

A valve fails here. A damper goes half way shut here. Or something else goes funny. So, if you go to air systems, I couldn't tell if you have or not looking at the partial states is even more important.

MR. CORUM: Yes.

MEMBER BLEY: Well, as important as.

MEMBER STETKAR: Air is -- they do evaluate air because it's the purge air through the tanks. But that's the only thing they've looked at as far as best as I can tell.

MEMBER BLEY: Yes. But it could be used for control too. That's what I was concerned about.

MR. CORUM: Yes. And -- yes, that's a very valid issue. And we will definitely look at that in final design.

I don't think we're at the point now where we've really decided how --

MEMBER BLEY: It doesn't look that way.

MR. CORUM: Yes. How our -- how our valves are going to be operated. So, yes. We will definitely take that into account going into final design.

So this just lists the process hazards analysis categories and accident sequence. The primary process nodes and the sub-processes that we went through systematically to come up with all of our hazards that we had lifted 107 nodes total.

Eight systems which we've listed on this slide and the following slide. And each sub-process within that created the 107 nodes that we looked at.

So, that's over the next two slides. And then we have another crosswalk for the process nodes and the top level accident sequence categories. Again, for the purposes that we talked about earlier.

So, on slide 15 we come up with what happened in our PHA. So we ended up with about 140 accident sequences that were identified for additional evaluation. Either qualitative or quantitative.

Seventy-five of those accident sequences were evaluated in QRAs. Eight QRAs are completed covering those 75 accidents. And those are listed on the right-hand side in the table.

And then we had one QRA that was completed covering the chemical accidents.

MEMBER STETKAR: Mike?

MR. CORUM: Um-hum?

MEMBER STETKAR: This may help a lot later.

MR. CORUM: Okay.

MEMBER STETKAR: Again, every word in each of those eight reports. The -- I think I can probably say this. In Chapter 13 PSAR, there is a uniform statement saying quantitative results will be provided in the final safety analysis.

So no quantitative results are provided in Chapter 13. Therefore, my basic question is, how should we today consider all of those quantitative analysis?

Will they be redone in their entirety?

MR. CORUM: During the final phase they will be looked at for the necessity to be redone. I believe in a lot of cases we will redo several of them.

I'm not sure that we're going to redo every single one.

MEMBER STETKAR: I was afraid of -- I was afraid you were going to be that equivocal, so. We'll -- I'll try to address a few things then this afternoon.

Because the numbers are A, in a state of flux. And I suspect considered proprietary anyway, so.

MR. CORUM: Sure.

MEMBER STETKAR: I'll talk a little bit about some of that this afternoon then. I just wanted to understand kind of going in, how I should think about those.

MR. CORUM: Yes.

MR. DUNFORD: I have just to add a little bit to what Mike said there. There are not a lot of -- well, there's -- a quantitative worker doses, you won't see any in there.

There's a couple of qualitative assessments of worker dose. Maybe. If you go look.

Yes. There's a couple.

For a qualitative --

MEMBER STETKAR: More than a couple. But --

MR. DUNFORD: Well --

MEMBER STETKAR: Go on. Go on.

MR. DUNFORD: If you go back --

MEMBER STETKAR: Fewer on the worker dose. I'll admit.

MR. DUNFORD: Yes.

MEMBER STETKAR: That's right.

MR. DUNFORD: And on the offsite public, there's a number of quantitative.

MEMBER STETKAR: Yes.

MR. DUNFORD: There's -- but if you go look at the QRAs, you'll find that there's only pretty much what's presented in Chapter 13 have good quantitative numbers or well based quantitative numbers.

And the QRAs, the qualitatives, just have estimates right now in a lot of cases. So, there's still -- and as I look at this, I still believe that we go back and we double check all the frequencies and all the accident dose calculations and plus complete the ones that we haven't completed.

But, we really are bracketed by what we

have completed.

MEMBER STETKAR: Yes. Let's talk more this afternoon when I can speak about specific things. Because I don't know where the fine line is between public and non-public information.

MR. CORUM: Okay. Let's go to slide 16. I'm just going to ask how you guys would like to proceed through these?

I mean, I know we've got a lot of tables, a lot of information here. I don't know how you guys want us to go through it.

I mean, line by line? Or how --

MEMBER STETKAR: I think you should go from each of the 1.3.1.1 --

(Laughter.)

MEMBER STETKAR: And describe to everyone what exactly that is.

MEMBER BALLINGER: And you should read the full number.

(Laughter.)

MR. CORUM: Okay. So are you guys going to be available tomorrow too? Okay. So I don't know if there are any ones in there that you would choose to talk about Gary.

This first page here primarily is

criticality. And we kind of went through that yesterday.

This is specific. This particular slide is for the target fabrication that --

MEMBER BLEY: So just a quick question. When we see all the numbers out in front, so those are all scenarios that are essentially the same?

MR. CORUM: These are scenarios that we developed during the PHA that we then groomed --

MEMBER BLEY: Categorized.

MR. CORUM: Into common consequences so that we could cut down the number of analyses that we did. Maybe what we could do is go to the uranium recovery and recycle that we kind of went through in detail yesterday.

MEMBER BLEY: But before you do that, can I ask you one about just the top one?

MR. CORUM: Oh, sure. Sure.

MEMBER BLEY: Because one of our previous meetings, I asked a question about double-batching. And somebody said oh, we double-batch by design.

Well, the double-batching here means twice what you've designed for, I assume. Is that correct?

MR. CORUM: Correct.

MEMBER BLEY: Okay.

MR. CORUM: It's -- yes, it could --

MEMBER BLEY: Which could take you to criticality.

MR. CORUM: It could if our vessels were designed differently. But we have accounted for that in the design of the vessels themselves.

MEMBER BLEY: But from what you said yesterday, not that you ever would, and there would be no reason to ever do this. But you could put more than four in a pot, right?

MR. CORUM: You could.

MEMBER BLEY: If I got part way through and then something happened. And we cleaned up a bunch of stuff. And then we came back and I said, oh, I only put one in. You could --

MR. CORUM: Yes. You could --

MEMBER BLEY: So you could eventually get to a place where you could go critical?

MR. CORUM: Not --

MEMBER BLEY: Or is it physically designed such that if you filled that baby up to the top and it still --

MR. CORUM: Physically designed that if it's completely full, fully flooded or optimally flooded that you're going to be safe. Safe by geometry.

MEMBER BLEY: Okay. Then I'm a little surprised that this one is resolved by administrative controls rather then saying geometry won't let this happen.

MR. CORUM: And again, this is at the PHA phase. Okay? So at this phase --

MEMBER BLEY: So help me out here.

MR. CORUM: Okay. At this phase, this -- this --

MEMBER BLEY: You didn't know that you had designed it the way you have designed it when you did --

MR. CORUM: At the PHA phase in this case --

MEMBER BLEY: The hazards analysis.

MR. CORUM: Maybe not.

MEMBER BLEY: Okay. So this is a potential. And now you've solved this in the end not by administrative controls, but by physical design.

MR. CORUM: Right.

MEMBER BLEY: Which makes me much more comfortable. If I worked there it would make me more comfortable.

MR. CORUM: I'm not sure at what point the crit-safety engineer was when they went into the PHA.

It doesn't sound like he had done any single parameter limit type scoping calculations at that point before he went in.

Because I would have expected that this would have been -- this would have been a different --

MEMBER BLEY: So you did this in the way one would do it. You did the PHA early on.

MR. CORUM: Oh, I'm sorry. Okay. I'm sorry, I know exactly why.

Okay. He did SPLs. This is target fabrication so we're doing --

MEMBER BLEY: SPL is?

MR. CORUM: Single parameter limit calculations.

MEMBER BLEY: Okay.

MR. CORUM: So he did do that. But this is target fabrication where we had the microspheres and he hadn't done evaluation.

MEMBER BLEY: Oh, whoops, we're in the wrong place.

MR. CORUM: I'm sorry.

MEMBER BLEY: We've got to save all this detail too later.

MR. CORUM: I'm sorry. Yes. Okay. Yes.

We were in target fabrication space.

MEMBER REMPE: So maybe this is also again me not understanding what I was reading. But like on the second line at 1.1.1.3 about the supplier ships greater then 20 percent you -- to 35 of the site.

A lot of places I read and it would say well, the license prohibits it. Which to me isn't a good safety mitigation action.

You know, there was other places I read and they said you have some sort of system that you would be able to detect that. Because I wouldn't rely on DOE always to do it correctly.

MR. CORUM: No. We wouldn't rely on that.

MEMBER REMPE: And I'm trying to remember where I read it different places. But there were a lot of places in that that said well, that violates the limit.

And I couldn't quite understand that. And I'd have to go back to some of those underlying safety documents that supported this, where I'd find that kind of stuff.

But to ensure me that there are detection systems in place that you would notice if it came in at a higher rate percent?

MR. CORUM: So this is done differently

at different facilities. Some do inspections at the supplier site before the delivery.

MEMBER REMPE: Um-hum.

MR. CORUM: To ensure that they're meeting the specifications that are in the -- in the agreement that NWMI has with them. Or that any facility has with them.

Other places do some confirmatory analysis when the material shows up. So, I don't know at this point that we've decided to do confirmatory analysis.

MEMBER REMPE: I thought I'd read, and I'd have to look, but Carolyn has some insights I guess.

MR. CORUM: Yes.

MS. HAASS: Sorry. I was standing over there. I don't want to -- let me hear.

So you're talking about slide 12.

MEMBER REMPE: Well, I just talked about what I read at this point.

MS. HAASS: But if you -- in -- with what the DOE has decided to do, we're not going to be able on this particular instance to go there and be able to do confirmatory analysis.

MEMBER REMPE: Um-hum.

MS. HAASS: We're going to have to rely on them to give us what they say they're going to do their analysis. And we won't be able to do any confirmatory analysis until it gets to our facility.

But in the uranium lease take back, or even if you bought the uranium, we have the ability to send it back if it doesn't meet specifications. So we will have to do it at our facility.

MEMBER REMPE: Yes. I thought I read somewhere you are going to do something at your facility to confirm it.

MS. HAASS: We are.

MEMBER REMPE: And it's a --

MS. HAASS: It's unfortunate we can't do it there. Because we really don't want it sent to us and then have to send it back.

But unfortunately that's not how DOE works.

MEMBER REMPE: I feel better knowing that you are going to do that.

MS. HAASS: Oh, yes, yes, yes.

MEMBER REMPE: Okay.

MR. CORUM: Okay. So let's continue. And I would propose that we go into the section on the uranium recycle and recovery that we kind of went through yesterday.

And go through that one maybe in detail. Well, maybe not in total detail.

(Laughter.)

MR. CORUM: We'll go through enough of it.

MEMBER STETKAR: You don't even want to do that.

MR. CORUM: We'll go through enough of it that we get a flavor for what was done. And then can spur some questions.

So the criticalities on slide 26, those should look familiar from yesterday. So, I think we'll -- we can skip through all the criticalities.

And on page -- on slide 27, we get to the -- a radiological consequence that is due to carry over of high vapor content gasses or solutions into the process ventilation header.

And can cause poor performance of the retention bed materials and release the radionuclides. And I think this goes straight to one of the ventilation situations that we could get into.

You can see this is from the PHA item numbers. This came up in a -- quite a few scenarios. Which I would expect. Because there are a lot of connections to process ventilation throughout the facility.

So, this one was done in a QRA, right?

MR. DUNFORD: Any that was SR, went to QRA.

MR. CORUM: Yes. This went to a QRA that we would have evaluated down in the process. And would have determined if it were a high consequence, intermediate consequence, if it needed IROFS, then we would have assigned the IROFS. Which, I believe this one did, so.

On slide 28 we have another radiological release from a solution that spilled from the system in the hot cell area. And somehow makes its way to impact the workers, the public or the environment.

Again, a large number of scenarios that led to this particular scenar -- this particular accident description.

Then we have again, this one was evaluated in a QRA. Go ahead.

MR. DUNFORD: So, I'll just use that as an example of the reason we've got to close the loop back even on the PHA what the final design is. As part of Chapter 13, we would analyze this accident in three different locations.

And we would have found that there was a whole family of nodes that doesn't have this kind of radiological impact here. So, the next time we go through, we would have now some data to go change that.

And we'd screen some things out a little different. And it would look a little different. So, there's a couple of reasons that we need to go back.

The other reason is, if this did have controls, we would use all these nodes to go back and figure out where we had to apply all those controls in the facility. So we had to map all of the controls back to the individual hazards and locations where we identified those hazards in the PHA.

MR. CORUM: So the next few are all radiological releases due to some type of incident or initiating event. The next one on slide 28 is you get spray of product solution in the hot cell area.

Again, we would analyze that in a QRA. The next one was high dose radionuclide containing solution leaks to the chilled water or the steam condensate system.

And that's a high does enough to -- for radionuclide concerns but not for criticality concerns. And that was -- would be analyzed in a QRA as well.

And I guess that -- Gary just pointed out that that was a separate criticality concern. So that one is a criticality concern, so.

Okay. On slide 29 we're looking at hydrogen buildup in tanks or systems that could lead to explosive concentrations. And we looked at that in a specific QRA where we had accumulation of flammable gas in tanks or other systems, so.

Then we have a higher dose then normal due to double batching and activity or due to buildup of radionuclides in the system over time. And here we credit the hot cell shielding as -- for the normal condition and mitigating safety feature for the hazard itself.

So, this -- this -- the shielding itself would be the IROFS for this particular event. To keep this event from occurring. Or not from occurring, but to mitigate it.

Then we have a high temperature, pre-elution or regeneration regent causes unknown impact on the ion exchange resin. And since it is kind of unknown, the consequence there could not be fully understood.

So, maybe Gary -- Gary, can you shed some light on that one? Because I'm not familiar with that one. Do you remember that?

MR. DUNFORD: We still identified a couple of open issues in our PHA and our accident analysis. This happened -- ion exchange, this happens to be one of them, so.

MEMBER KIRCHNER: On that subject, can you perhaps might regress to the target dissolution accident sequences? Because there you have a number you identified that potentially you could impact the performance of the iodine recovery units.

And then lead to large releases. Have you examined those in more detail qualitative -- quantitatively?

It seems to me this is the set that you identify here looks like one that needs more attention so to speak. You -- because you identify so many, you know, paths to impact the performance of those IRUs.

MR. DUNFORD: Yes. So in Chapter 13, that's the second accident discussed in 13.23.

MEMBER KIRCHNER: Yes.

MR. DUNFORD: Is actually -- it was a family of accidents.

MEMBER KIRCHNER: I hear you. Yes.

MR. DUNFORD: Dealing with the iodine.

MEMBER KIRCHNER: So, I guess where I'm going with this is, what about -- what is it about this family of sequences that you would -- what would you do in the design of the plant to mitigate this?

I mean, they serve the IRUs. It's an essential function to keep your dose below your limits.

MR. DUNFORD: We'll walk through that in

detail in Chapter 13. Even in the public session.

MEMBER KIRCHNER: Okay. All right. I'll wait until then. Thank you.

MR. DUNFORD: All right.

MEMBER REMPE: This is back to this one on slide 29 --

MR. DUNFORD: Okay.

MEMBER REMPE: That was the open item. Is this one where you're doing research? Because I know we're going to have something later this afternoon. Unfortunately I think I'm going to miss it when you do whatever it is on the experiments and tests.

But, how many -- what type at a high level -- is something like this something that's being -- there's some experimental testing being done?

I believe what I read was for like the red oil stuff. You're doing some experimental work also. And at some point are you going to talk in this session or in the open session for 13 about the type of data that's being obtained to address some of these open items?

MR. DUNFORD: We don't have anything planned in the presentations right now to go over that. But I guess we can in the closed session talk a little bit about what we've identified for testing.

MEMBER REMPE: Okay. I have a conflict. So if you can do it when I come back later in the day, I sure would like to hear it.

But, I can get it from the transcript if I can't. But thanks.

MR. DUNFORD: Okay.

MR. CORUM: Okay. Continuing on slide 29. We've got a spill or a spray of low dose condensate. And that we kind of screened out as a low consequence of -- and just contaminated surfaces and dose to the worker below the intermediate consequence dose levels.

Slide 30, we're looking at a high uranium content product solution directed to the high dose waste collection tank. Oh, we're in waste handling. Sorry.

Okay. That's -- so that was uranium recovery and recycle. Yes. We could -- yes. We could go through waste handling too.

Because that is where we have some unsafe or non-favorable geometry vessels that we would be making transfers from. Favorable geometry too non-favorable. So, it might be useful to look at how we did those in the PHA.

The first one was a high uranium content is directed to the high dose waste collection tanks by accident. And that could result in a criticality accident in the high dose waste collection tanks.

So we have looked at that in a QRA as well as in criticality safety space in the CSE. And addressed that by sampling and holding until we make that transfer.

(Off microphone comment.)

MR. CORUM: Okay. Then the next one was a high uranium content. The solution enters the low dose waste collection tanks by accident. That's very similar to what we have talked about on the high dose waste collection tanks.

So, we did look at this from a QRA standpoint and a criticality safety standpoint. We did use a different control strategy for this one.

I think it's more of a continuous monitoring and a lag storage until we release to the low dose tanks from the condensate tanks -- storage tanks.

So, then we have a -- the third one is high uranium content accumulates in the TCE reclamation evaporator. And so we looked at that one in a -- in a QRA as well.

Then we have consideration of uranium products accumulating in the silicone oil waste stream. And so we've looked at that one also in a QRA.

Hydrogen buildup in tanks lead to explosive concentrations. This is the same fire QRA that we've looked at on the previous system that we considered.

Then we have several tanks or components that are vented to the process ventilation system overflow. And send high dose solution into the process ventilation system components.

And this could be a radiological release to high dose to workers and the public. And we've looked at that in a QRA. And I think we'll talk a little bit more about that in Chapter 13.

The purge air system allows high dose radionuclides to exit the boundary in an uncontrolled manner. So we'd have high dose solution back flowing into the purge air system potentially.

And that we analyzed in a QRA for radiological concerns, so. So, I'm just trying to look through here to see if there's any that are really.

MR. DUNFORD: So what this got turned into really, those QRAs were done and there is really a couple of big families of accidents.

Sprays and spills as a family, dissolved rock gas, Walt, that you are asking about, because of what it is, where it is, the inventory it is, and leaks in the auxiliary systems or chemical addition systems and stuff in either the steam lines, condensate line, chem additions line.

Those are the three large families of accidents and controls that we looked at that are in 13 and they have some estimate of, a quantitative estimate, too, of offsite impacts.

The other, and then we, obviously, as you guys already know, the next part of Chapter 13 we'll talk about is what happens under loss of power and then we go to the series of the natural phenomena and then the rest of the chapter is a summary of, a brief summary of the other nominally 60 accidents or whatever is left out of the 75 where we talk about, okay, here is what the accident sequence is and here is the controls that we believe are, that are IROF level of controls at this time.

So that's what this PHA really takes us to, right. It gave us these families of accidents we have that we had to look at.

We did that through the QRA process and then we transferred that QRA into Chapter 13, various bounding-type accidents to show, at least from the PSAR, we don't have all of the data in there, in the FSAR we will have all of the data in there, but to understand that we understand the facility, the family of accidents, and we believe we have a robust control set that will protect those we have identified and those that we may yet come up with or modify as another initiate or another sequence or something like that.

CHAIR CHU: Gary, could you repeat what is the third category?

MR. DUNFORD: Leaks into auxiliary systems. So into the secondary steam system or backflow into a chemical addition line or a transfer between two areas that doesn't have -- well, it goes through an area that doesn't have safe criticality for, and that has to be -- double wall piping would be another example.

There is kind of a family of things that says the solution has gone where you don't want it to go. Obviously, sprays and leaks are, you know, they are not an unlikely event, right, they are a likely event. So those are also very important. Do you have any other takeaways --

(Simultaneous speaking.)

MR. CORUM: No. I think with that I think we can kind of conclude this portion because we'll get into a little bit more detail in Chapter 13 on where this, all this information flows, so unless there are any questions -- Okay.

MEMBER POWERS: Do you look at ammonium nitrate accumulation in your system?

MR. DUNFORD: We have recognized that that is a potential area in target fabrication actually and we've gone through the evaluation, it's in the process description, the discussion of it, and what happens to that, filter change out and some things like that.

As part of the PHA, I don't remember where it showed up or if it showed up as a unique item, I know as part of the continuing work we have been doing that that is something we have identified and we have looked at it, again, qualitatively, and think that non-IROF level of controls are appropriate.

MR. CORUM: Okay. If there is no further questions then we'll move on.

CHAIR CHU: Okay. Staff?

MEMBER POWERS: The problem that never ceases to amaze me when it occurs is, in fact, radiolytic hydrogen generation within piping systems, and I think you identified that in your survey, how do you assure that that doesn't occur?

MR. DUNFORD: Let's see, how do I answer this question. In our facility small pipes, short transfer times, flushes after transfer, disengaging tanks in the secondary system, like pulling water that would allow any of that to buildup, obviously, in non-pipes purger and emergency purge gas system.

So we are somewhat familiar with what other facilities are trying to go, at least in the DOE arena trying to go through, and we just -- So far we haven't seen a situation that looks like we are going to have a similar situation.

So that's kind of where we are, short transfers, flushes afterwards because we want to get all the material to the moly system, et cetera.

MEMBER POWERS: Yes, well, they just -- When they occur it just always surprises the hell out of me because it just never -- it's only after the fact that it dawns you that you could get an accumulation of both hydrogen and oxygen in that particular location.

MR. DUNFORD: I guess the other thing I'll add is we have in our process spec -- Well, that's the only thing I guess I can talk about. So all of the stuff that came out of the PHA and IROFS we have actually in all of the controls from the criticality we have reloaded that back into the updated process spec so that the design agents have a system-by-system, what other sets of controls and stuff they have to be applying in the final design, which systems need date tanks, which systems need backflow, which have doubleblock valves, where they apply and stuff, so that's been done.

And I forgot where else I was going to go on that comment, but -- So we still have some more work to do, but we'll talk about Chapter 13.

MEMBER POWERS: In your system you don't ever have liquids pressurized at high levels, do you?

MR. DUNFORD: Radioactive streams? I mean, obviously, we got pressures on the cooling water and the steam system. The only place that I think I mentioned it yesterday that really sees, and I'm not going to use the word "high pressure," but a low pressure, is the uranium recovery systems.

Those act like a column and a column has a pressure drop and, therefore, they are going to be running.

MEMBER POWERS: But it's not a huge --

(Simultaneous speaking.)

MR. DUNFORD: Oh, no, it's less than 50 psi, I believe.

MEMBER POWERS: Yes, that's just -- I was just thinking of your spray droplet size, but you don't have any high pressure systems here that would give you very tiny droplets?

MR. DUNFORD: No.

MEMBER POWERS: No.

MR. DUNFORD: However, we use some very conservative values in our analysis.

CHAIR CHU: Okay.

MR. BALAZIK: Good morning again. My name is Mike Balazik, a project manager for the Northwest Medical Isotopes Project.

Next to me is April Smith from NMSS. She will be giving the ISA methodology presentation today. Next to her, again, is Dave Titinsky from NMSS. So let's go ahead and get started.

MS. SMITH: Thank you. All right, so good morning. As Mike said I am April Smith. So I have heard rumors that you guys are excited to talk to us about the review, especially the ISA portion.

And now that you have heard from the applicant I don't think I can make things any more exciting. As a matter of fact, I am going to make it kind of boring because now we are going to talk about the regulatory requirements.

You can go to the next slide. All right, we are there already. And I think you will notice a suspicious lack of 10 CFR Part 70 underneath the regulatory requirements, and that's for a couple of reasons.

So, first of all, we are in the construction phase and we're looking at the -- The target fabrication part of the application isn't here yet and that's when the 10 CFR Part 70 will really become involved.

But the other reason why you don't see 10 CFR Part 70 here has more to do with the second bullet for acceptance criteria.

Next slide, please. And that provides some context to this review, and that is the ISG that augments NUREG-1537. Part 2 states that an ISA methodology as described in 10 CFR Part 70 and 1520 is an acceptable way of demonstrating adequate safety for construction. However, that applicant is free to propose alternative methodologies.

So with that context we are more less looking for reasonable assurance that the appropriate pieces, the right elements are present that support the adequate identification of capabilities in the future to prevent or mitigate potential accidents and protect the health and safety of the public and workers, so I want to make sure we have that context.

We are looking for the right pieces at this point. So to do that we reviewed this seemingly short list, the ISA methodology as presented in Chapter 13, the ISA summary which in my mind also includes the QRA, and other information that is throughout the entire PSAR, such as Section 3.5, you've heard about Chapter 9, Chapter 11, we're going to talk more about Chapter 13, and there we are looking for consistency and implementation of the ISA methodology, the designation of IROFS, systems and components important to safety, and when applied to the design basis at this early stage in the design whether or not those things have been done consistently.

Next slide, please. So our review included an evaluation of the ISA team, certain definitions and their application, or I should say implementation, and we've already heard some questions from Drs. Bley and Stetkar in that sense, and like credible, what does that mean with respect to many unlikely actions, no motive or reason, so things like that were the type of things that were looked at.

And we also looked at the description of the ISA methodology and its demonstrated implementation of the ISA summary.

Next slide. So the next presentation, Chapter 13, is going to give more details on each one of these processes, and you've already heard quite a bit of detail from the applicant, but I just wanted to give you an idea of the scope of our review.

We looked at these processes as a demonstration of the applicant's application of its ISA methodology.

Next slide. All right, so now let's get into what that methodology is that you just heard the details of how the applicant applied it to ISA methodology and those primary pieces are listed here.

They performed a hazard analysis. They primarily used a structured what if and HAZOPs to do that. They performed a qualitative assessment of likelihood consequences at risk with the risk category.

And then based on the results of the qualitative assessment they then performed the QRAs for those that were indeterminant, intermediate, or high risk events.

Then that is followed by an identification of accident sequences which then led them to the determine the IROFS and the boundary package definitions.

So with these pieces we have those elements that gives the staff confidence that we have a representative set of the accident sequences that we expect to see and that they are going to be able to apply this in a way to essentially root out those processes that need IROFS.

So before we go to the next slide, actually the next three slides you have already seen from the applicant, and it's basically covering the consequence categories, the likelihood categories, and the risk matrix.

So unless anyone is going to have any special questions I don't know why we would cover that again, so skip the next three slides.

MEMBER SKILLMAN: April, you just said at the end of Slide 8 you are looking for the accidents that you expect to see.

MS. SMITH: A representative set.

MEMBER SKILLMAN: How about the ones that you didn't expect? You know, this is kind of nuclear 101, you don't know what you don't know.

MS. SMITH: Oh, okay, so let me clarify. Okay, so they have set up a methodology that is going to allow them to go through process by process and identify particular accident sequences.

So what I have confidence in is that this methodology, as systematic as it is, will allow them to do that. So the set of accident sequences that they have supplied, I wouldn't say that I know that that those are all of the accident sequences or even that I had expectations going into as to what those were.

I have confidence given the large scope that they were able to return a very comprehensive list that this methodology is going to be capable of finding those accident sequences.

MEMBER SKILLMAN: Fair enough. Thank you, April, thank you.

MS. SMITH: Okay.

MEMBER STETKAR: April?

MS. SMITH: Yes?

MEMBER STETKAR: Just to get it on the record, did you look at their PHA, in particular the items that were screened out, not retained, and ask yourself do we agree with what was screened out?

MS. SMITH: So --

MEMBER STETKAR: I am asking you yes or no. I want a yes or no answer please.

MS. SMITH: Okay. So ask your question again.

MEMBER STETKAR: Did you look at their PHA, in particular the items that were screened out, that were not retained, for further evaluation and draw a conclusion that those were adequately screened out, that there was an adequate basis for screening out?

In other words, go through that long laundry list that they have and every item -- You said, well, they have a big list of stuff that they retained, okay, did you look at the stuff that they screened out and say, yes, we agree that it was reasonable to screen that out, that it doesn't need to be looked at? Did you do that?

MS. SMITH: And I know you want me to say yes or no --

MEMBER STETKAR: If you want to qualify it, I'll -- Whatever you want to put on the record.

MS. SMITH: But it's not -- Yes, it's not that simple. So 1520, as part of 1520 that is what we do as our review. It is listed in 1520 that you will also make sure that you are checking for those things that they had screened out, okay.

For this phase and the maturity of their design and where it is right now I did not specifically ask for PHA.

MEMBER STETKAR: Okay, so you didn't --

(Simultaneous speaking.)

MS. SMITH: As we go -- For those that they, for those things that they screened out.

MEMBER STETKAR: So --

MS. SMITH: I am leaving that, and you will see this later on. So we are leaving those things for --

MEMBER STETKAR: For the FSAR?

MS. SMITH: For the FSAR.

MEMBER STETKAR: So there could in principle be things that the staff raises questions about that should have been included in their sequences that might result in IROFS and you won't address those issues until the --

MS. SMITH: Yes, not for construction, but later.

MEMBER STETKAR: Okay.

MS. SMITH: Yes.

MEMBER STETKAR: I just wanted to make sure I understood what the staff has done and what the staff hasn't done.

MS. SMITH: Sure.

MEMBER STETKAR: Because the material is obviously available.

MEMBER REMPE: So just to follow-on on that, yesterday there was a lot of discussion about all we are doing is giving them basically a permit for pouring concrete and we've tried to identify things that we think they may need to consider and is this point also carefully, and maybe it is and I've missed it in your reviews, or in your SE at some place, that, you know, by the way we may -- what John is asking is that carefully communicated to the applicant is what I am wondering?

MS. SMITH: So as part of the SER, and, Mike, correct me if I am wrong, we will have the opportunity to highlight certain areas of when the FSAR -- These particular things have been referred to the FSAR in order to review them for X, Y, and Z.

MEMBER REMPE: Yes, okay. So they understand that, too?

MS. SMITH: Yes.

MEMBER REMPE: Thank you.

MEMBER BLEY: I find this a little troubling and it goes back a little bit to a discussion we had yesterday where the staff reminded us that it's kind of up to the applicant to decide what they are going to submit and take their chances on the rest. Well, here they did submit something --

MS. SMITH: Yes.

MEMBER BLEY: -- that could have been reviewed and we decided not to look at it and now the staff, I'm sorry, the applicant's, even though they put it in here, they are going to wait until they submit their request for an operating license to find out that, gee, you took something out you shouldn't have an now you got to change the design.

It just seems not consistent with what we talked about yesterday.

MS. SMITH: Okay, I understand your concern and as the design matures quite a bit of this information is going to change. You've already heard the applicant say that.

MEMBER BLEY: They're probably not going to look back at the stuff they screened out.

MEMBER STETKAR: Yes.

MEMBER BLEY: That's probably once and done unless you folks come back and say, oh, you shouldn't have screened that stuff out. I don't think that's going to be part of the evolving design, at least not the way I understand it.

MEMBER STETKAR: And what I hear is you are looking at what's there, you're not looking at what's not there.

MS. SMITH: But that's what you hear at this point for --

MEMBER STETKAR: You're looking at the sequences that they've accumulated things into, looking forward.

MR. TITINSKY: Can I -- Let me add, this is Dave Titinsky, I'd like to add a little bit more to that. That's not exactly true. I mean reviewers specifically for the various disciplines, and you'll hear about some of them, like the chemical events, are looking at events that aren't necessarily in what was in the Northwest application.

I mean it's the responsibility of reviewers. You look at the events that they propose, that they say are intermediate or high consequences, but a reviewer's responsibilities are also to look at, to think about things that they haven't considered.

So that is -- so, again, we're at a preliminary design stage, so you look at it, but it is preliminary and Northwest will be submitting a full ISA summary and have all the backup information available in the final SAR, for the final SAR that we will review in greater detail to come up with some of those things that you're talking about, looking at the specific events, and we would expect that the PHAs, or however they screen them out, that the information would still be available for reviewers to look at and determine whether they agreed.

And, again, something that may be screened out now when they bid a final design may not be screened out or vice versa just based on how --

(Simultaneous speaking.)

MEMBER BLEY: I think the vice versa is much more likely on that one to tell you the truth.

MEMBER STETKAR: The things that bother me is you immediately said, well, individual reviewers for individual processes will certainly look at individual things.

I am talking about a systematic staff examination of the PHA, going through those things. In particular, in particular, the line items, and there is a large number of them that they screened out, and having confidence from an integrated staff perspective that they had adequate justification for screening them out.

It's not an individual process, somebody who understands the chemistry of a particular process. That's a staff going through a submittal.

It's possible to do that today and saying does their rationale for saying that this event is already highly unlikely from a frequency perspective that the consequences are insignificant from a consequence perspective, that it's not credible whatever rationale that they used in there. Does that make sense? Do we agree with that?

MR. ADAMS: So this is Al Adams. I think you make a good point and what we will do is between now and next time we talk to you in September we will take a look at this and, you know, come back and discuss this with you some more.

MEMBER STETKAR: Okay, Al, be careful, because it's going to take a while for your staff to go through that whole thing. It's huge.

MR. ADAMS: Yes.

MEMBER STETKAR: If you really want to talk, think about line items. I mean there is -- It will take a while, so don't make commitments --

(Simultaneous speaking.)

MR. ADAMS: Well, I'm not --

MEMBER STETKAR: In terms of process I --

(Simultaneous speaking.)

MR. ADAMS: I am not committing that we are going to do a review, what I am committing to is we will look at it some more and try to come to, you know, think about is this a, you know, is this a good spot to do a complete review of this or, you know, is the design still changing, you know, or what we need to do.

MEMBER STETKAR: Okay.

MR. ADAMS: I think, you know, you make a good point and we will take your point and think about it some more and come back and talk to you about it.

MEMBER STETKAR: Okay. Okay, thanks. I just wanted to make sure that you didn't get yourself into a bind where you are going to have your staff burning many, many hours between now and September to try to go through that thing.

MR. ADAMS: I appreciate that.

MS. SMITH: We understand.

MEMBER REMPE: And I think it's important that the applicant understands this, too, because I mean this kind of occurred with SHINE also and, you know, there is a lot of folks that -- I think the agency needs to make sure everybody understands what was done and what wasn't done and everybody agrees that the appropriate -- The applicant may say I don't want you to go through those screened out things because we're going to change the design so much that it's not worth it, we just want to go ahead, but make sure everybody agrees and it's well documented.

MR. ADAMS: Right. So there is, you know, similar to SHINE what we plan to do is as part of the SER have a comprehensive list of items that the applicant has said, yes, I know about this, you know, you're going to see it in the FSAR that we capture that items we discussed at these meetings that need to be specifically flagged for the FSAR.

So we will have a list of items that, you know, we need to pay attention to when the FSAR comes in and, you know, I think it's, again, a decision, you know, as we said before, you know, the applicant has to give us enough information that we can do a construction permit review and issue that construction permit.

Once we get past that point the applicant makes the decision on what risk they want to take on pushing things into the future.

MS. SMITH: Absolutely.

MR. ADAMS: And, you know, they are sitting there, they are clearly I think receiving the message from us that decisions come, you know, that these decisions come, you know, with some level of risk that, you know, when we get to the FSAR we can come back and say, you know what, you screened these six things out but now that you have finished your design and we have looked at them, we're not so, you know, we have questions.

MR. TITINSKY: Can I add one more point about, you know, we do the review and we have, obviously, people assigned to various disciplines. We don't do it in isolation.

So when a reviewer in one area finds something that they question or want to know in different discipline we have team meetings and other stuff, and so we communicate between, you know, various disciplines to try and cover it.

So we try not to silo, we try and work as, you know, one unit, one team, here to do the review.

MEMBER BLEY: When it's quiet keep going.

(Laughter.)

MS. SMITH: Oh, is that how that goes?

MEMBER STETKAR: By the way, this slide highlights a little bit of my concern because it says review areas deferred to FSAR. If you look at the third bullet all of those immediately focus on what I will call the technical reports that define the IROFS for the things that are retained, do the analyses of the likelihoods and consequences for each of those retained sequences and so forth.

I don't see anything on here that says comprehensive review of the PHA, that it's deferred to the FSAR and that's why I wanted to bring it up here.

MS. SMITH: Okay. We can physically add that to the list, but I think as you have already heard that we were certainly planning on doing that. It's part of NUREG-1520 as part of the review.

MEMBER STETKAR: It's perhaps NUREG-1520 needs to be revised.

MS. SMITH: Oh, so, wait. Okay, maybe you misunderstood what I said, because it's part of NUREG-1520 to do that type of preview.

MEMBER STETKAR: Okay, okay, I'm sorry, I misunderstood you.

MS. SMITH: Okay, yes.

MEMBER STETKAR: Okay.

MS. SMITH: So it's definitely in 1520 and I think we find that in a lot of our standard review plans that you want to make sure you are seeing whatever they say doesn't apply, you want to verify that.

Okay, so -- And perhaps the previous conversation is a good segue into this one as we are talking about as the design matures and we have already heard from the applicant that things are going to change.

And so these are the areas that we have deferred to the FSAR, so demonstration of the IS-18 qualification and training to appropriately assess event frequencies and consequences, demonstration of the appropriate hazard analysis based on the associated hazard.

So if it's a complicated process, a complicated system, make sure you are applying an appropriate analysis technique. So no checklist for something that's a huge system, for instance.

And demonstration of compliance with the performance requirements, that will include the adequate technical basis established for likelihoods and consequences, an appropriate application of terms for likelihood and credibility, a review of those IROFS boundary packages, and the IROFS to establish, to prevent or mitigate as needed.

And in my mind that also includes the issue that you keep bringing up to make sure that they actually haven't screened out something to which they should have applied IROFS, and then the adequate management measures for those IROFS that they have established.

So, next slide. So given the description of the ISA methodology and demonstration of its implementation in Chapter 13 of the QRAs the applicant has provided reasonable assurance that its proposed integrated safety analysis methodology contains those elements that we are looking for to support the adequate identification of capabilities and features to prevent or mitigate potential accidents and protect the health and safety of the public and workers.

And as we also discussed, further technical or design information will be deferred to the FSAR. Okay, do you have other questions?

MEMBER KIRCHNER: So can I go back to Slide 11? So this is the kind of the risk matrix, yes. You do this early on as part of this process. Now when the FSAR comes in do you look at what I will call the gray areas?

We talked about this earlier, you know, interfacing systems, events. This is rather stylized --

MS. SMITH: Yes.

MEMBER KIRCHNER: -- and convenient and it's the process, I understand it. I'm not trying to change the process, but it seems to me what about the things that are rated five?

MS. SMITH: Correct. So, again, that falls into this category --

MEMBER KIRCHNER: Yes, okay, in this category, too.

MS. SMITH: Yes, absolutely.

MEMBER KIRCHNER: So do you systematically --

MS. SMITH: So, yes, we do look at that as well.

MEMBER KIRCHNER: -- go back to the top, so to speak, and go back down through this again to see that what came in initially still bins the same way and, no, this one is kind of gray?

And then do you -- I think you have a supplemental slide that suggests what I am asking, that you then go and do the in-depth dive into that.

MS. SMITH: So before we would get to here we are going to be looking at the way that they categorized their consequences and the way that they categorized their likelihoods and at that point we are assessing whether or not they have done that appropriately, or they give us adequate assurance that for those particular accident sequences the initiating event is, in fact, the ten to the minus three, or not unlikely or highly unlikely.

MEMBER KIRCHNER: All right.

MS. SMITH: That then gets combined with the likelihood category, which then translates to this table. So before we even get here we would have answers to the question that you just asked.

MEMBER KIRCHNER: Thank you.

MS. SMITH: Yes. Anything else?

CHAIR CHU: Anymore questions? If not, we'll take a 15-minute break and come back at 10:40 a.m.

(Whereupon, the above-entitled matter went off the record at 10:23 a.m. and resumed at 10:42 a.m.)

CHAIR CHU: Let's resume the meeting and go to Chapter 13. Thank you.

MS. HAASS: So we are going to give our overview of Chapter 13. I want you to know we are on our last 50 pages of the presentation, this very bulky presentation.

MEMBER BLEY: You look very happy.

MS. HAASS: Well, no, because I am feeling better, but --

(Laughter.)

MS. HAASS: Yes.

(Simultaneous speaking.)

MS. HAASS: So no matter what anyone says I really can't hear, so, okay. But so we are going to give a quick overview of 13. Please realize we have a lot of tables in here as well.

You know, we were trying to -- We want to focus where you guys want to go in this public session. We know that we only have an hour, we know there is lots of questions, but do have time this afternoon as well.

So I am going to hand it over to Gary and then Mike and Steve will also support the presentation when the questions come up, but Gary is going to take the lead on this. Thanks.

MR. DUNFORD: Thanks, Carolyn. So we'll just start on Slide 2, Steve. Good man. So some of this intro material we have already talked about. There is a couple of things, and I guess I kind of want to lead with is we still know we have more work to do.

In the QRAs there is assumptions about we assume this is a high worker dose and, therefore, but we don't necessarily have done anything, we have not completed a quantitative analysis in some of those areas yet.

The other thing I want to talk about, a little different than the CFR 7061 criteria is we have said that a shielded or an unshielded criticality event we consider that a high consequence event to the worker even though it's an unshielded discussion in the actual guidelines.

And a couple other things I want to point out, if we have identified a hazard in the PHA that doesn't mean we don't have controls for those hazards. It just means that they were screened out from the standpoint of IROF level type of controls.

So just kind of keep that in mind. It doesn't mean there is not a control if we screened out a hazard or even if we screened out below an IROF, there still would controls, defense in depth, and we want to make sure that the facility is safe for both the worker and the public.

So we'll go to Slide 3, please. So the things we are going to talk about are the sprays and the spill accidents, which has both a radiological and a criticality implication.

Dissolver offgas accidents, or the family thereof, which is a radiological family of accidents, leaks in the auxiliary systems, which also could be radiologically or chemically impacted, a loss of power accident, and then we'll go through natural phenomena and then the other accidents that I briefly mentioned earlier which is the other family of items that are in the QRAs but not brought into Chapter 13 in a lot of detail yet.

We'll try to walk through the way the chapter looks through each of the accidents, those five areas, initial conditions.

We're not going to talk -- Most of the source term data is actually proprietary, so we won't actually talk real numbers when it comes to source term, but we'll talk about what is the source term from a standpoint of it's this much material or here is the assumptions that we made into it.

Initiating events, description of the accident sequence, there is functional barriers for some of the discussions, the unmitigated likelihoods, and, again, an emphasis on the unmitigated consequences because those are the ones that need IROF level of controls if they are above criteria, and then identification of those controls.

Some of them had mitigated -- Well, the ones that are quantitative have also mitigated doses for the public. Mike went through this earlier, and that's the family initiating events that 1537 tells you you got to make sure you cover at least that family of events.

So Slide 5 is the start of the sprays. We evaluated three different process streams for sprays or spills. Effectively that would be the highest dose we could hypothesize, which would be the process tanks where we hadn't removed any fission products.

So actually I think on this category, yes, it's really the second bullet. We also looked at dose solutions that are on the back end of the uranium system.

There is a large number of tanks there so there is a lot of nodes that were looked at. And then we also looked at the moly product, the spill of the moly product after we were trying to take it out of the hot cell.

So Calculation 0-11 is our source term calculation and -- Was that one we shared, boss, 11?

MS. HAASS: Yes, sir.

MR. DUNFORD: Okay, thank you. So in that you can see the analysis of liquid source terms, different locations, started with a basis of our mass balance in some cases.

In some cases we went to actually what was in the target at an 8-hour decay and we then built a number of conservatisms into what we called our source term for each of the accidents, and some of those will come out here.

For the target dissolution stream or the worst case stream that we have there is about a factor of 1.32 nominally is what conservatism is what we are kind of starting with in that stream. It was actually a little bit more than that, but that's what we quantified.

So we have a process equipment failure, you could have an operator error, or the accident itself could be initiated by a fire or explosion that would bust a pipe or bust a line.

In the PHA, as we looked at in the ISA summary, this type of accident was pretty much in every section. Target fab had it from criticality, the other sections had both radiological and criticality dose consequences.

So tank leaks, this is just kind of walking through the sequence of events. There is a similar thing for a spray, the process vessel fails or someone makes a mistake that causes it to empty to the floor, which is probably noticed by the sump level or the floor area alarm or a change in the liquid level.

We suspend operations, identify where the leak came from, and eventually the system won't be stabilized until we actually had taken the material off the floor and put it back in one of our waste tanks for cleanup.

MEMBER KIRCHNER: Gary, so what is the nominal plan for sumps and drains like this, where would you preferentially redirect such a fluid if you had a spill, a line leak, or something, even if it doesn't result in an "accident" per se, where would you move that material to?

What is your contingency plan in the plant layout to deal with spills regardless of the accident?

MR. DUNFORD: Yes. So let's just use the large hot cell, it has the most tankage and stuff in it. We really don't have like a fine, sump slope area where you can get more than two inches, so the whole thing is pretty flat.

MEMBER KIRCHNER: Right.

MR. DUNFORD: So we actually have a concept that we actually have a vacuum tank or a pump that we actually -- We have an in-cell manipulator that we could go suck up in the floor in the area of concern.

MEMBER KIRCHNER: Like a swimming pool cleaner or something, a robot or --

MR. DUNFORD: Maybe not that complex, we'll see. I mean, obviously, the in-cell manipulator can work on that. I have seen those pool cleaners. They are not really --

(Simultaneous speaking.)

MEMBER KIRCHNER: I mean because you are at the point now where you are designing, or you're going to design the layout of the piping --

MR. DUNFORD: Yes.

MEMBER KIRCHNER: -- if that is your cleanup mechanism then you need a, pipes need to be --

MR. DUNFORD: Overhead.

MEMBER KIRCHNER: -- six inches above the floor or overhead or whatever so that you actually can do it.

MR. DUNFORD: Yes. Coming into the top of the skid is probably where we end up with most of the piping I have.

MEMBER KIRCHNER: Yes.

MR. DUNFORD: So that you have access to that and the only thing then in your way is the dunnage from the skids itself.

MEMBER KIRCHNER: Yes. But there is no plan to have a sump that is pumped into yet another tank because then you have criticality and other issues that you don't want to --

(Simultaneous speaking.)

MR. DUNFORD: Yes, so we want to wait.

MEMBER KIRCHNER: -- to cleanup.

MR. DUNFORD: I mean you could say that I am going to put, you know, Brasic, Boron or something in there, but then you create an issue of how do you know they are there five years from now.

MEMBER KIRCHNER: Yes.

MR. DUNFORD: So based on -- We've gone to the geometrically favorable flat floor.

MEMBER KIRCHNER: Right.

MR. DUNFORD: Spray leaks, similar, right, other than that's happening and why it's pressurized, so you are generating potentially an aerosol right away as opposed to in a dump you might have more of a splash situation as covered by the standard handbooks for how you do accident analysis, and we'll talk a little bit about that.

So the process vessel enclosure, the floor, the walls, the ceiling, they all where we end up, and to be honest this is kind of where we started, we obviously knew we had radioactive material, it was a hazard, so we had to have a hot cell.

So actually even as part of the PHA, and you'll actually see that in some of the PHA answers, we said we already have shielding here, this doesn't change our condition in the hot cell or anything like that.

So we already had accredited the hot cell structure itself. So we have a barrier that is effectively our stainless steel liners in our large, I will use the large hot cell as the example.

We have a ventilation system still operating, so stuff that does get aerosolized is going to go into the vent system, and as I said we really don't have a sump per se, but we have the ability to clean it up and to stabilize the situation.

We said the sprays is a not unlikely event, i.e. it's going to happen, ten to the minus one type of event. We did look at the Savannah River database, which is what WCRS-TR 93262 is, it's a pretty comprehensive database on equipment failures, operator errors, and stuff. Very useful for a RAMI type analysis.

So I mentioned the three things we did, which would be the low dose tanks which in this situation I think were decayed for 500 hours, effectively eight hour decays, the second bullet, and the last bullet is our total product coming out of our moly system, again one liter, it's less than one liter there.

There should be nothing magic on the next slide. These are NUREG-6410. Let's see if I have data. Yes, I do, on the next slide. So, obviously, what's your material at risk, what's your damage ratio, what's your born release fraction, respiral fraction and is there any kind of leak path reductions in here.

So in our analysis we used a 100-liter spray leak event. Effectively, if it was just the mirror which we use as like a radiological basis, you'd probably only have like 25 liters to start with, but, again, another conservatism that we add into the analysis.

And in that spray leak event, and what we do is we end up with the iodine going out the stack effectively in a non-mitigated, but we didn't take any credit for any of the HEGA filters or the HEPA filters initially.

And what we end up is the -- So that's an intermediate consequence event. Now you're going to look at the data and you're going to say, well, how is that an intermediate consequence event because in 7061 that's actually five rem for an offsite public and we are below that but right now we started off as this is going to be either a high worker consequence or it's going to exceed the environmental line in the intermediate hazard event which is the 5000 times Table 2 value I believe it is in a 24-hour period.

MEMBER KIRCHNER: Now, Gary, you made conservative assumptions going in in terms of amounts of material and such, can you go through the justification in this particular case for an airborne release factor of, let's see, 0.0001?

If it's the dissolved, the initial dissolved fluid, do you have any concerns about thermal, well, you've got fission products so it's going to be hot, is this 0.0001 for the airborne release factor actually conservative for a hot solution that's been sprayed?

MR. DUNFORD: Yes. You're talking about what we get to the respiratory?

MEMBER KIRCHNER: No, what just comes up as part of your source term and goes through your stack. So basically you're --

(Simultaneous speaking.)

MR. DUNFORD: Yes. Well, the short answer is, yes, I believe our analysis is conservative. I am not sure what value you're actually looking at --

MEMBER KIRCHNER: I didn't say that. I didn't -- I said your inputs were conservative, but when you apply that factor is that conservative? You've got hot fluid that's sprayed on the floor --

MR. DUNFORD: Right.

MEMBER KIRCHNER: -- is that going to carry over and up into your ventilation system and go right through and increase your airborne release?

What I am testing you on is is the 0.0001 actually conservative for this situation where you have a potentially hot fluid.

MR. DUNFORD: Well, it's out of the handbook. I believe it is.

MEMBER KIRCHNER: Okay.

MR. DUNFORD: So, I mean I can -- So you're talking --

(Simultaneous speaking.)

MR. DUNFORD: Yes, you're talking about the airborne release fraction?

MEMBER KIRCHNER: Yes.

MR. DUNFORD: Yes.

MEMBER KIRCHNER: So you are basically assuming then there is no carryover of liquid or vapor?

MR. DUNFORD: Well, there is. I don't believe you're going to get a bulk carrying of vapor off a floor.

MEMBER KIRCHNER: I don't know how hot it is. I was curious how hot will the solution be when it's being dissolved?

MR. DUNFORD: Well, we dissolve at 90, 95 degrees C.

MEMBER KIRCHNER: So since --

MR. DUNFORD: So that's very hot.

MEMBER KIRCHNER: Yes.

MR. DUNFORD: And then it's cooled and then it's transferred --

MEMBER KIRCHNER: What if it weren't cooled?

MR. DUNFORD: It sits in the dissolver and cools.

MEMBER KIRCHNER: No, you dissolved it and it's hot and now you have the spray.

MR. DUNFORD: I have to turn the pump on to make a transfer for the spray. But --

MEMBER KIRCHNER: No, it just leaks.

MR. DUNFORD: Okay. So I guess I'm not, I'm not tracking, I apologize.

MEMBER KIRCHNER: If it's -- What did you say, 95 C, it's close to --

MR. DUNFORD: 95 C, okay.

MEMBER KIRCHNER: Close to the boiling point, right?

MR. DUNFORD: Well, it's --

MEMBER KIRCHNER: You spray it out of a system --

MR. DUNFORD: -- 2 ml of nitric acid so it's 10 degrees or whatever you want to say.

MEMBER KIRCHNER: Yes. Isn't there going to be vapor evolved from that hot fluid in the relatively, in a situation where it's just spraying out?

MR. DUNFORD: Yes, you'll get some evaporation.

MEMBER KIRCHNER: And so what I am testing you on is --

(Simultaneous speaking.)

MR. DUNFORD: If the water will evaporate.

MEMBER KIRCHNER: Yes. So --

MR. DUNFORD: Some water will.

MEMBER KIRCHNER: Yes. So what I am testing you on is the assumption of the airborne release factor of 0.0001 for a hot fluid that is spraying out of the system.

MR. DUNFORD: Yes, I'd think it's based on the handbook and the analysis, I think it's not a bad value.

MEMBER KIRCHNER: Okay. Just testing.

MR. DUNFORD: Okay.

MEMBER KIRCHNER: I'll go back and look at the handbook, too, and see if it's at room temperature or close to boiling.

MR. DUNFORD: I failed and incomplete on it.

MEMBER KIRCHNER: Because you have other scenarios where you do worry about carryover into your ventilation system.

MR. DUNFORD: Well, and that's where I want it to go, obviously, because I have iodine removal on my ventilation system, right.

MEMBER KIRCHNER: Yes, and you want that all to work.

MR. DUNFORD: Yes.

MEMBER KIRCHNER: But I'm saying so you have situations where -- I'm just testing whether this indeed is bounding.

MR. DUNFORD: Okay. So under the -- I don't think actually -- Yes, that data is not in here. So in the unmitigated case the second and third bullet, or actually it should be a single bullet, so the nearest permanent resident is about 300 millirem exposure and then the maximum exposure is still our 1100 meter receptor which has a TEDE of the 1.8 rem.

MEMBER SKILLMAN: Your 32 meters and 0.27 miles don't really track at the second --

MR. DUNFORD: Yes, well, that's because --

MEMBER SKILLMAN: It's probably 320 meters.

MR. DUNFORD: It's -- No, there is a four, it's 432.

MEMBER SKILLMAN: 432, all right, that's better.

MR. DUNFORD: There is a four in there.

MEMBER SKILLMAN: Okay.

MR. DUNFORD: I didn't catch that typo. So then in this accident the mitigated consequences are at our magnitude in the document and that's because we have a HEGA filter and we took a -- While the HEGA filter itself can have a decontamination factor of 1000 we took a factor of ten as what we used to accredit in the analysis which dropped us below the guidelines in the criteria, and that's what this curve is there, and that curve is obviously in the document.

So the spray has, the spill of the spray end up then where you have what are the issues, right, you could have a radiological release, aerosol or fission product gasses, or you can have a criticality concern going to an non-geometrically favorable location, and you got to protect the workers.

So we end up with the family of radiological controls 01, 03, and 04, which we talked about infinitum previously, which would the ventilation system, the shielding, the primary tanks itself, in this case would fail in the primary tank.

And then we also have the criticality that deals with spacing and sump and floors and the double wall piping which would be if you had that leak as you are making a transfer between a geometrically favorable location to a geometrically favorable location, but if went through a, to a pipe chase some place that may not drain that so you'd have to have a double walled pipe in those locations.

So that was the -- So the accident is the spray. That's actually the last slide here. You have a leak in the hot cell, ventilation system is still working, shielding is still working, and we ended up accrediting the HEGA filter in the Zone 1 exhaust system as the interim safety feature of the IROF.

Next accident, a little bit of a question you asked earlier this morning on the dissolver offgas. So in the hazard analysis a loss of iodine removal during a dissolution had a number of different initiating events.

You could lose efficiency, flooding in the scrubber system, loss of power turns out to also be an initiating event. Once you have added the nitric acid to the dissolver it's going to go probably fairly slowly if there is not heat, but if happened when there was close to planned temperature you would end up with a continuing reaction.

So as we went through this accident we actually end up as a preventative feature, I guess I'll say mitigated feature of the accident, and we'll talk about that, which is a collection tank that is there to, a vacuum tank to be able to absorb the whole volume of the dissolution.

Okay, so family of accidents that affect the IRU. We went through an analysis trying to understand the captured material that was on the IRU, the previous dissolutions, the previous iodine that was already captured on our silver-mordenite, silver zeolites.

Did we have an accident where we could see where that could be released, and we didn't really come up with a credible mechanism or even a physical mechanism where that was going to happen.

I mean we looked at heating the material, and you wouldn't see any reactions that -- we're going to replace the iodine or displace the iodine off it. So we're really just going to end up with, you know, in this accident the ongoing dissolution of four MURR targets as our initial condition.

Eight hours after EOI, which it means it just comes into the plant, we really, what we have seen and what we kind of project is that 20 percent of our iodine probably would stay in our solution going over to the moly recovery system and about 50 percent of the iodine that actually did go overhead would be captured in our NOx removal system, that 50 percent probably primarily in the caustic scrubber, and then go to the high dose waste.

For this analysis we assumed that all of the iodine that was in the targets at eight hours is going overhead and the material at risk.

So I kind of talked about initiating events, high gas flow, moisture carryover, the loss of temperature, and all those affect the efficiency.

We also assumed that the target had just started dissolution. So, again, the material at risk is everything that's in there, and we -- Okay, so the material started.

We've got some type of process condition. The events are identified by an operator that is IRU or -- removing them is not working right either because there was some alarm on the heater temperature or there was a radiation alarm on the gas stream indicating that we had some breakthrough of the system.

Following procedures, they would turn off steam, they'd switch, you know, part of the operating they could probably switch to another IRU. We can just ignore that for right now.

So we had the accident, it comes out, it has a significant dose to the offsite public, that amount of iodine going out the stack.

The last initiator here on the sequence, the last bullet says "If initiated for event in the loss of power grid, the vacuum tank would open." So I really jumped ahead. So we designed into the process, or, actually we already had a design in the process, this vacuum tank.

On loss of pressure this tank can hold the full complement of a dissolution and, therefore, even if nothing was moved in the IRU it still would be captured. So as part of this that's actually what we ended upgrading to an IROF level of control is this tank.

MEMBER KIRCHNER: Gary, could you describe the physics of the IRU units you are proposing to use and what's the capture principle and how they operate and what's the likelihood of upset with carryover and so on?

I mean what is the, you know, the media that is being used in these that you --

MR. DUNFORD: Silver zeolite or silver-mordenite.

MEMBER KIRCHNER: Yes.

MR. DUNFORD: Which then would produce silver iodine --

(Simultaneous speaking.)

MEMBER KIRCHNER: Right. Now are these susceptible to fires?

MR. DUNFORD: No, I would not expect them. Not that we --

(Simultaneous speaking.)

MEMBER KIRCHNER: Am I going into -- I can save it for --

MR. DUNFORD: Proprietary?

MEMBER KIRCHNER: Sorry.

MR. DUNFORD: Should we -- No, I don't think there is anything proprietary in what you asked for.

MEMBER KIRCHNER: Yes. Now what you described is what typically is used for iodine recovery.

MR. DUNFORD: Right. Yes. And it operates warm. I mean, it's 150 degrees c, roughly, inlet temperature. It's a fairly small flow rate we're talking about.

MEMBER KIRCHNER: Right.

MR. DUNFORD: The flooding of a column, flooding of, you know, moisture carryover, those are likely events. They're going to happen in a process.

MEMBER KIRCHNER: Right.

MR. DUNFORD: So you can have some moisture. And typically, what the moisture would probably do, would just put a load on the heater and you probably wouldn't get the optimum temperatures you're looking for, for removal. So any of those things, they're going to cause a loss of efficiency of the bed.

The bed will still be efficient --

MEMBER KIRCHNER: Right.

MR. DUNFORD: -- to some. Not to three nines or something, but even at room temperature it still is efficient.

MEMBER KIRCHNER: Right.

MR. DUNFORD: And it's still going to remove, we don't have it in here but we looked at that separately, still going to remove 30 or 40 or 50 percent of the iodine.

MEMBER KIRCHNER: Right.

MR. DUNFORD: Even at room temperature.

MEMBER KIRCHNER: So there's no danger of having some kind of exothermic reaction or something that would lead to fire in the bed?

MR. DUNFORD: Again, not there. And even the units that we have upstream are wet. So as far as our unit operations and how they look, we just didn't see that as, again --

MEMBER KIRCHNER: Okay.

MR. DUNFORD: Because the issue is, what's already there is an inventory that's about four times higher than what we just analyzed as a release.

MEMBER KIRCHNER: Yes. Thank you.

MR. DUNFORD: Yes.

MEMBER POWERS: Your carryover is going to come primarily from your organic iodine?

MR. DUNFORD: The breakthrough, yes.

MEMBER POWERS: Yes.

MR. DUNFORD: Yes, it has less of efficiency, that's very true. And actually, that's part of the issue, even when you look at the spray, they're going to talk about it is, how much of that is organic iodine versus elemental. And they have different capture efficiencies.

MEMBER POWERS: But you don't have a lot of opportunity --

MR. DUNFORD: Not at that stage.

MEMBER POWERS: -- to form organic iodides in this. You'll get some just because of cram material.

MR. DUNFORD: Yes.

MEMBER POWERS: And I should think that your caustic scrubbers are much more efficient than you've allowed.

MR. DUNFORD: Could be. Again, for the accident we assume they're not efficient at all.

MEMBER POWERS: Hmm.

MR. DUNFORD: And if they were more efficient, that would just actually mean the inventory that we ignored in the analysis was lower than we thought it would be.

So this is a kind of a discussion of what the barriers are. So if the IRU, the primary capture device wasn't working or had reduced sufficiency, it still would remove some.

We also have iodine guard beds after the primary noble gas absorber. So that would also absorb some of the iodine.

The process vent system directs, still is directing the material, either through the primary process vent system or actually to the pressure relief system. So these are all barriers, so it's not just going all over the place, it's still in the piping, still in the primary piping in this accident.

And the other thing we did not accredit in this is, even after the dissolver offgas system, the PVV system itself has another IRU. So there's a series of multiple change and defense-in-depth.

Where we, again, where we used to actually mitigate this accident as we pedigreed the collection tank in the system because it's most effective. And it's a single location.

So now this is actually the frequency discussion. Again, very, assumed it's a not unlikely event. We've already talked about what we didn't take credit for and what we did.

There's the safety factor. Also applies, that I talked about in spills also applies to our generation term. In our generation term and our bounding analysis.

MEMBER KIRCHNER: Gary, how did you come up with the 1.32, is that somehow drive by standard practice or regulation or --

MR. DUNFORD: No. It was our engineering judgment. We had, in our mass balance, energy balance, we don't track all potential 600 plus isotopes --

MEMBER KIRCHNER: Right.

MR. DUNFORD: -- we track 100 plus. Roughly right around 100. So at different phases, that accounts for different amounts of the isotopes.

MEMBER KIRCHNER: I think when you truncated that though, didn't you just round up, wasn't that the, well, I am forgetting how you did the multiplication and the order you did it.

MR. DUNFORD: Right.

MEMBER KIRCHNER: I thought you did 20 percent --

MR. DUNFORD: Ten percent for not accounting for all the isotopes --

MEMBER KIRCHNER: That's what it was.

MR. DUNFORD: -- and then a 20 percent margin on top of that.

MEMBER KIRCHNER: And 20 percent margin, okay.

MR. DUNFORD: And that's where we got the 1.32.

MEMBER KIRCHNER: That's how you got 1.32.

MR. DUNFORD: Yes.

MEMBER KIRCHNER: Thank you.

MR. DUNFORD: Yes. So, Slide 19 is the unmitigated consequence analysis that was a ratio to some work we had done as part of the environment, in the environmental report, Chapter 19 area.

And it actually turns out, and this number is actually probably higher than it is, just because the ratio of iodides is different than what we analyzed.

So this direct comparison, I think since this time we have done an analysis, it's pretty close to the 5 rem instead of 6 point, but it's the same number. And it's something you have to prevent and mitigate.

So again, we got the same, if you look roughly the 400 meters, that's your closest resident. And then the 1,100 meters is the maximum exposed.

Chapter 20, I'm sorry, I keep saying chapter, I apologize. IROFS RS-03 on Slide 20, this starts going through what has been accredited. And it's the primary offgas relief system is accredited.

We've already have the primary, or the hot cell secondary confinement system is also in that and also have been accredited in here. We actually in the off, in the analysis we did not, I believe, analyze the removal efficiency of that in this accident, because the lower IROFS mitigates it completely.

Defense-in-depth, monitoring of the stack that would tell us we had a problem. We do have the spare IRUs, so if we did have a flooding event or a problem with one of the trains, we do actually have two other trains.

And again, defense-in-depth perspective, the carbon beds that we have that are quite extensive also would at least slow down and do some iodine absorption too. Any questions on that event?

Okay. The third event, okay, so let me just, we have other IRUs. They would be bounded by this event because their source terms would be dramatically less at material at risk, any one or two-hour period.

Orders of magnitude, much more than orders of magnitude less. So we still have to then go apply these controls, appropriate controls, to those other locations. As part of our control application and going through the PHA again.

Okay, leaks in auxiliary systems, both a criticality issue and a potential fissile. Or I'm sorry, radioactive issue for the workers.

In fact, this probably does pretty much just create a worker event. Depending what's going to go out the stack, if it was a real criticality.

Okay, initial conditions. You have a tank, it's jacket is, and there's multiple vessels that are a jacket of tanks that have coils, I'm sorry, not coils, jackets, and are filled with solution.

You also could have a similar condition in the evaporators that we have. Again, that would be a leak into the steam system versus into a cooling water system.

We also have condensers. Again, similar thing. Condensers typically would see a lot lower inventory then what we got analyzed here.

So the PHA identifies that it leaks somehow. There's the initial conditions, and we're going to continue that.

We used a bounding source term, would be the dissolver feed or the feed tanks in the moly recovery. Even I'll admit in the construction application, I don't think there's actually a jacket on the moly tanks. I think we're adding them, but there's not one in the value --

Those initial source. So again, we used a very conservative source term and applied that.

Just kind of going through, see what else we need to talk about. So the leak in the second containment is the hazard to the worker.

So the PHA, so you could have a corrosion issue, you know, that causes an issue. Over pressurization could potentially be an issue.

To be honest, we've looked at that as part of our Chapter 5 analysis. We really don't see, at least a structured tank as bought and built, that we really see an issue there.

But anyway, either one of those types of events creates a potential for that to get into the secondary system.

MEMBER KIRCHNER: Gary, is it safe to say that your design approach is that all the secondary or auxiliary systems will be at higher pressure than --

MR. DUNFORD: Yes. Yes.

MEMBER KIRCHNER: -- the process lines that actually have the uranium and/or fission products?

MR. DUNFORD: That's correct. And it's also safe to say that they will, the loops are, the inside loops are geometrical favorable expect for a one loop that we have identified on evaporators, condensates, that is not. So even if it did leak, we have a control that says that's going to leak into a geometrically favorable situation. So then we still are preventing a criticality.

I think I'll just move on to Slide 24. So effectively we're saying now that the process solution has leaked and got into this, there was still kind of an initiating events scenario.

As I've said, we've already accredited that this, we've already designed into the systems are geometrically favorable. But at the time we did the PHA, and when this first came out, that wasn't necessarily the case. It was, but it wasn't accredited as an IROFS I guess I'll say.

Okay, going through this analysis. Let's see, is there anything we haven't talked about. Does anyone have any questions on, again, this is just talking about the events happening and how we might have detected that event. The change in the condensate conditions, the PHA, the liquid level alarm.

Because obviously, if you have a higher-pressure media you actually detect the leak by the tank that is leaking. Solution going up is typically what you'll see instead of the solution going down.

The Slide 27 is barriers. So we had failure of the geometrically safe vessel. It also provides containment for the solution.

So all we're really trying to say here is we had initial barrier and we end up then with really the secondary loops become the barriers that we end up, those closed loop systems. Because the solution does not leak into those.

So there's still a barrier in the hot cell that keeps that material from leaving the hot cell.

MEMBER KIRCHNER: May I ask? For leaks, at least on the cooling water system, you're going to put a conductivity or a PHA detector, are there any radiation detectors, outside primary confinement, to look for such a issue?

I don't know the detail layout --

MR. DUNFORD: No. There are area --

MEMBER KIRCHNER: -- yet of your cooling system and steam systems, but would you have --

MR. DUNFORD: Area radiation alarms? We have identified on some streams that we would have a single purpose monitor there.

MEMBER KIRCHNER: I would think just for worker safety.

MR. DUNFORD: Correct. And part of the radiological program --

MEMBER KIRCHNER: But then it could double as a means of telling you you've got a leak.

MR. DUNFORD: Right. So there's defense-in-depth.

MEMBER KIRCHNER: And it might be more reliable then, I guess we're not supposed to give you advice, are we. Never mind.

MR. DUNFORD: Yes, conductivity --

MEMBER KIRCHNER: Conductivity is, sometimes is not the best way to detect what you're looking for.

MR. DUNFORD: Okay.

MEMBER KIRCHNER: I'll stop there.

MR. DUNFORD: I won't write that down then either.

(Laughter.)

MR. DUNFORD: Conductivity concern. All right. We ended up with, again, a not unlikely event. We've already kind of, the scenarios of what can happen, we've already kind of gone through.

And on Slide 30 there's some estimate about fissions and that's, the third to the last bullet is ten to the 16th and ten to the 17th fissions. It's not 116 fissions. Or 1,000.

MEMBER KIRCHNER: But can you put that in context, that's a few fissions. What's the dose from that many fissions?

MR. DUNFORD: In a non-shielded event, death to the worker.

MEMBER KIRCHNER: Yes.

MR. DUNFORD: Fatality.

MEMBER KIRCHNER: Fatality, yes. I just wanted to put that on the record, that's a lot of fissions for an unshielded event.

MR. DUNFORD: It's coming out of a standard Los Alamos document.

MEMBER KIRCHNER: Yes, I know it.

MR. DUNFORD: Okay.

(Off microphone comment.)

MR. DUNFORD: Well these would, that's what I said, these would be --

MEMBER KIRCHNER: -- shielded.

MR. DUNFORD: -- we're still assuming any criticality needs to be prevented though, in this case.

MEMBER KIRCHNER: Correct.

MR. DUNFORD: And if it happened in a target fabrication, obviously that is an unshielded area, and this covers that.

MEMBER KIRCHNER: Right.

MR. DUNFORD: So, based on the consequences, you have to mitigate, and you have to -- you have to mitigate the radiological, and you have to prevent the criticality.

So the shielding hot cells, the hot cells shielding, excuse me, provides the prevention of the worker dose from direct exposure. The hot cell shielding boundary I guess is what is called RS-04 and it's used pervasively through our IROFS level of controls. So you'll see that quite a bit.

Then you get to the CS-06, which is our pencil geometric favorable type of controls. And eventually we're going to get to CS-10, which is now that those closed-looped cooling systems have to be geometrically favorable.

And if they're not, as in CS-27, then you have to have other methods to ensure that your loop is okay, your system is okay.

In this particular case, I think I'm on the next slide, yes. Well, yes, I am going to go.

So there is the looping, the loop itself has to have monitoring alarming capabilities, and the condensate itself on CS-20, also has to be monitored to make sure that there's not any uranium in that stream. We don't expect it to be there.

And if there is, and then you bypass and just recycle back to the, essentially it stops the process.

MEMBER KIRCHNER: This is a continuous monitoring?

MR. DUNFORD: Yes, these are both -- yes, continuous monitoring. I'll use that word. Batch monitoring.

MEMBER KIRCHNER: Batch monitoring.

MR. DUNFORD: While you're doing the batch. Backflows. So auxiliary systems include chemical additions, air purge systems.

So you have to have some way to prevent material from getting back into those solutions, or into those systems. Auxiliary systems so to speak.

And I think you asked earlier about the and the or's. Whether you have backflow prevention or a day tank. In some cases, you ended up with both.

So criticality prevention, safe geometric tanks, day tanks. So that's CS-18 and 19.

Which also showed up in the CSE that we talked about this morning. Or yesterday.

So defense-in-depth, tanks will be vented and normally un-pressurized for normal use. So again, it's a mode of force, but still.

And this goes to your question earlier, the heating and cooling systems operate a higher pressure than the process solutions. Vented tanks have level indicators.

So there's monitoring, the ability to identify if you had a leak into the tank from your cooling water system, is an example.

We have batch operations, typical low volume. And so we have the ability to handle some of these perturbations.

So obviously, some of the way you can get to an auxiliary system would be overflowing a tank and then backfilling it up. So that's what these defense-in-depth discussions are talking about here.

Corrosion of wall thickness. Purge gas, we'll have check valves in our reagent lines and our bridge gas systems too.

I think as we actually go through, we'll have to figure out whether those have to be accredited as an IROFS level control. It could just end up being the design of the system, but that's one that may end up, as we do the rest of the control suite, where that ends up at.

MEMBER KIRCHNER: Gary --

MR. DUNFORD: Yes, sir.

MEMBER KIRCHNER: -- can I go back to 32?

MR. DUNFORD: You sure may.

MEMBER KIRCHNER: I know we asked this, and maybe I forgotten the answer already yesterday, what are you monitoring uranium content with, in this background, in this field?

MR. DUNFORD: Yes, so this, the concept here is that this condensate stream enters a shielded area away from the hot cell.

MEMBER KIRCHNER: Okay.

MR. DUNFORD: A low dose area so that we can have some type of spectral monitoring of the stream itself.

MEMBER KIRCHNER: Okay, so it won't be in the background of --

MR. DUNFORD: No.

MEMBER KIRCHNER: -- the fission products?

MR. DUNFORD: Even if that would work in the background, you would fry the electronics too quickly, more than likely.

In fact, in the overall layout I think we talked about, their location is specified just because we want access to be able to come out into a smaller hot cell, so we can do that evaluation there.

MEMBER KIRCHNER: So the uranium detection system de facto becomes a piece of safety equipment, QA Category 1 as part of IROFS CS-20?

MR. DUNFORD: Yes, sir. And I actually think that IROFS might call for two detectors, I can't remember.

Okay, so that was, that's again, that's a very large family of accidents. Go ahead, sir. No, okay. I thought you were ready to jump in there. I'm going to --

(Laughter.)

MR. DUNFORD: Well, you look like you're ready.

MEMBER KIRCHNER: You're on the edge, right?

(Laughter.)

MR. DUNFORD: Okay, so very, the discussion this morning about utility systems and partial failures, and very good advice to make sure that we incorporate that into our FSAR and our evaluation. When we have a little bit better, when we have a final design, or close to the final design that tells me, that's an air system, that instrument is going to work on an electronic system, that we can do that evaluation and have some validity. So it's a very good point.

Okay, loss of power. Is the initiating event for a large number of the hazards we looked at, the initiating event for the, what I'll kind of classify as our, we don't use bounding accidents per say, but the dissolver offgas system is one initiating event for that accident, which so far as generated the largest unmitigated dose that we have evaluated.

So this is what's going to happen in loss of power. There are a number of systems that are on UPS, uninterruptible power supply, the process control systems, communication, security, emergency lighting, fire alarms, criticality, incident alarms, radiation protection systems, and I'm missing something there. Okay, since I can't remember what it is I'm not going to worry about it.

Loss of power occurs --

MEMBER BLEY: Have you --

MR. DUNFORD: Yes.

MEMBER BLEY: You haven't worked out yet how long your UPSs are going to stay powered, have you?

MR. DUNFORD: We have no, well, go ahead, you want to answer that, John?

MEMBER STETKAR: Chapter 8 says --

MR. DUNFORD: Yes.

MEMBER STETKAR: -- the fire protection UPS is 24 hours.

MR. DUNFORD: Twenty-four hours.

MEMBER STETKAR: Everything else is two hours.

MR. DUNFORD: One twenty minutes, yes.

MEMBER BLEY: That sounds vaguely familiar. Thank you --

MEMBER STETKAR: You're welcome.

MEMBER BLEY: -- I'm glad you're representing the Applicant today.

MEMBER STETKAR: Well no.

MR. DUNFORD: Okay, so this is the exact same slide that we went over in Chapter 8. Discusses what happens to the Zone I ventilation system, to the process vent system, which will go back to that question earlier on Chapter 9 this morning about whether that valve fails or stays open, it will stay open in our design.

The pressure relief system that we just talked about, up above for the dissolver offgas accident, would open.

And the emergency purge gas system, which we talked about as part of Chapter 6, and it's probably talked about later in this analysis also, would activate so that those tanks that we have, as a potential for flam gas, would continue to be purged.

Again, I just want to reiterate, the purge flow rate, even for those high heat tanks, the high activity tanks, is really still pretty small. Most of them under a CFM.

The uranium concentrator lines, we just talked about the criticality controls on the uranium monitoring system and the condensate. Those valves would open so that there would be no uranium getting into an auxiliary system or into a system that wasn't critically safe.

And, what is the last one. Oh, wow. All, our pumps should all shutdown. And our secondary loops would all shutdown. So none of those loops are on a backup power supply.

Operator follows the alarm response and we state that the system is in a stable condition. So, out of this, obviously power failure is a, not an unlikely event.

Since we looked at this previously as an initiating event we had no, we identified just loss of power did not generate any additional controls.

And we do have a standby generator, a defense-in-depth feature. And it's really there from an economical perspective, from a business perspective. And we talked about, again, that in Chapter 8 also.

Do you want to do the next ones?

MEMBER KIRCHNER: Gary --

MR. DUNFORD: Yes.

MEMBER KIRCHNER: -- is possible, under an extended loss of power event, you shut down all of your systems, you no longer have that pressure differential from the auxiliary secondary systems to the primary processes, could the primary processes then self-pressurize because of decay heat or other reactions, chemical, such that the pressure then, in the primary process lines, exceeds the pressure in the auxiliary systems?

MR. DUNFORD: Yes.

MEMBER KIRCHNER: And/or the purge system, which I believe is nitrogen, isn't it?

MR. DUNFORD: Yes, emergency purge system is nitrogen.

MEMBER KIRCHNER: Yes. Or the nitrogen system over pressurizes the process lines.

MR. DUNFORD: So the Chapter 5 evaluation evaluates the loss of coolant and the conditions. And we, even in a plugged vent line, so there was no way for the pressure to escape, we demonstrate in there that we would not challenge the boundary of the pencil tank itself.

But the question you asked, would we be a higher pressure than the --

MEMBER KIRCHNER: The auxiliary secondary --

MR. DUNFORD: -- medium, the answer is, yes, we would be.

MEMBER KIRCHNER: Yes.

MR. DUNFORD: Yes, we would be.

MEMBER KIRCHNER: So if you sat there for an extended period of time, then that may become of concern.

MR. DUNFORD: You still have the primary confinement boundary is still not --

MEMBER KIRCHNER: Sure.

MR. DUNFORD: -- damaged, not, you know, so we're not damaging during this extended outage. So I would say you would not expect to see, I mean, on restart, if you saw something, then you might figure out you had a pinhole leak or something.

MEMBER KIRCHNER: Yes.

MR. DUNFORD: I'm just what-iffing now, from an operation perspective, but I don't think --

MEMBER KIRCHNER: No pinhole leaks in the nuclear business, that's --

MR. DUNFORD: That's right, you would not expect that. We don't have any stress cracking corrosion, we have none of those activities going on. So, okay.

Do you want to talk about this, they're all the same answer.

(Off microphone comment.)

MR. DUNFORD: Yes, I didn't think so. Go ahead.

MR. CORUM: Mike Corum for Northwest. I'm going to be going through the natural phenomena events analysis.

And I'll just preface it, I think we've said it before, we do recognize that we are proceeding at some regulatory risk, in the final design, with our natural phenomena events analysis. And we do anticipate having that completed before we actually start any construction activities.

So, with that said, we are going to look at tornados, high straight-line winds. We will look at meteorological conditions and historical meteorological events to do our analysis. And we will use finite element modeling for the wind load analyses.

We do anticipate, however, that the seismic load is going to probably be bounding for all of this, but we will take a look at the tornado and high straight-line wind impacts. As well as tornado missiles or any other missiles that are generated from high straight-line winds.

From a heavy rain standpoint, and we're going to look at the roof capacity of course, any SSCs that are important to safety, located outside the facility, lighting strikes. And I don't see it on here, but we will be looking at heavy rainfall that would cause, oh, okay, never mind, it's on the next page, the heavy rainfall that would result from an extreme runoff from the higher ground that's North of the site and how that would impact the facility or any SSCs.

MEMBER BLEY: Did you look at, well, you haven't gotten to snowfall yet, but did you look at rain after you already have a heavy snowfall, adding additional weight?

MR. CORUM: We haven't so far, but --

MEMBER BLEY: I saw different responses over there.

MR. DUNFORD: But that's part of the methodology for the structural evaluation.

MR. CORUM: Right. Right.

MR. DUNFORD: Yes.

MR. CORUM: Yes. Okay.

MEMBER STETKAR: Just for the record, in the open session here, we did, in our comments on Chapter 2, have some questions about the frequency, event frequency, that was assigned to some of those external hazards.

MR. CORUM: Right.

MEMBER STETKAR: Seismic is an obvious one, but straight-line winds my recollection was, I don't remember what the other ones were, which would factor into the analyses once you get into a quantitative assessment.

MEMBER REMPE: So, even though you've not done it yet, you've done like, just loss of offsite power evaluations and other evaluations in a lot of details, do you have a feel for where you're going to have some problems with a seismic event causes that loss of offsite power and what systems really need to be protected or which things might be real susceptible? You said seismic may be your most challenging one so I assume you've done some work that way.

MR. DUNFORD: Yes. So in Chapter 3 we identify seismic categories of systems.

MEMBER REMPE: Okay.

MR. DUNFORD: And those that need to be, so in safety system, those that need to be, both have integrity and perform their safety function, are identified as CS-1. Or C-1, excuse me.

And those that still have to have integrity, but don't necessarily have to function, so they don't fall on something or we just, those are CS-2.

So yes, we have systems. So the emergency purge gas system we just talked about it, it's a CS-1. So it has to withstand the seismic event. And still be functional after the seismic event.

MEMBER REMPE: So your approach is to hopefully have the same type of result as what you've done with your loss of offsite power right now, is you're going to protect the systems that need to be protected.

So you don't think you're going to have much differences in the results you're seeing, is that a way to characterize what you think you're going to have happen with a seismic initiated loss of offsite power?

MR. DUNFORD: Yes, I think that's fair to say.

MR. CORUM: Yes, I think so.

MEMBER REMPE: So in all the work you did, I mean, the Staff is going to be up here next, but they're probably going to talk about the fact that you left off a red oil event, and do you want to comment on why, I mean, there was an RAI and you responded back and said, we're doing research in that area, and why was that not included? Or any considerations of it.

MR. DUNFORD: Well, so what, I look at Dana to answer this question. So red oil is, historically has been a solvent extraction media associated with nitrate at uranium streams. Under, typically, evaporator conditions I guess I'll say.

We don't have those kinds of conditions in our facility. We don't have those kind of solvents --

MEMBER POWERS: They're not doing the, they're just not doing the kind of --

MEMBER REMPE: But the Staff, again, I'm not the expert in this, but they identified the --

MR. DUNFORD: They asked the question, and I thought we responded back. But we --

MEMBER REMPE: But I thought your response back said we're doing research, is what I read.

MR. DUNFORD: We're doing some work on ion exchange media. I don't believe we addressed red oil.

MEMBER REMPE: On the DAP stuff they talked about?

(Off microphone comment.)

MEMBER STETKAR: Carolyn, you actually have to, if you're going to say anything, you have to come up to the microphone. Sorry.

MR. DUNFORD: Well, effectively Carolyn was just indicating that she --

MEMBER POWERS: They don't have temperatures that are conducive to red oil formation, they don't have the chemistry conducive to red oil formation. There is just no --

MEMBER REMPE: That's what I would have expected them to say back and that's why I was curious about the response back.

MEMBER POWERS: I just don't see a red oil issue here. They're not using any of the hazardous reductants that were associated with extraction plants.

I just don't see a hazard here. Now, on the other hand, you still have to be very cautious about your bottoms and any of your evaporators, and what not. You've indicated that you're going to clean those fairly regularly --

MR. DUNFORD: Correct.

MEMBER POWERS: -- and keep them reasonably purged.

Those are strategies that would mitigate red oil if, if by some, I mean, our understanding of red oil is at best primitive, and so you can't say there is no red oil here. Because we don't, as I sometimes have said, red oil is not always red and it is definitely not an oil.

But what you're doing, it seems to me, handles any accumulation of an explosive or combustible organic polymeric material that might accumulate in the system. I mean, you're taking the precautions that we would if it was a red oil system. But it's not.

So I just don't see it. I mean, I just cannot identify something that's a problem here. You got enough headaches using uranium metal, you don't need any more.

Typically we have to get, we get worried about red oil at temperatures around like 130 degrees centigrade. And then you got to have the chemistry available to you there. And I just don't see that in the system.

MEMBER REMPE: Aren't they up to like 120 in some places? 123 c --

MEMBER POWERS: Yes. So, since we worry at 130 and 130 being greater than 120 --

MEMBER REMPE: And degrees gives you lots of confidence.

MEMBER POWERS: It does indeed.

MEMBER REMPE: Okay.

MEMBER POWERS: In red oil it does indeed.

MEMBER REMPE: I didn't know that. Again, I'm not an expert in it, but 10 degrees doesn't seem like a whole lot. Especially if --

MEMBER POWERS: Well, Joy, if you look at activation energies, you will find that 10 degrees in an aqua system is a bunch.

MEMBER REMPE: Okay.

MEMBER BALLINGER: It's likely to be a factor of four.

MEMBER REMPE: Okay.

MEMBER BALLINGER: Okay. Every 5 degrees centigrade is about a factor of two.

MEMBER STETKAR: Turn it on instead of off.

MEMBER BALLINGER: Every 5 degree c is roughly, correct me if I'm wrong, roughly a factor of two.

MEMBER POWERS: But it depends on the activation energy.

MEMBER BALLINGER: It depends on the activation energy, but for general chemical processes, 10 degrees is a --

MEMBER REMPE: Okay.

MEMBER BALLINGER: -- significant number.

MEMBER POWERS: And you still have to get, you have to have the chemistry that we think of. And they just don't have it.

MEMBER BALLINGER: I use a cooking a turkey example in class. Dry it, raise the temperature from 325 to 335 and ask yourself how long it takes for the little button to pop out of Ms. Butterball.

MEMBER POWERS: That actually is a pretty good analogy.

(Laughter.)

MEMBER BALLINGER: And it works. I've done it before and it works.

(Laughter.)

MEMBER BALLINGER: The turkey sucks but it works.

(Laughter.)

MR. DUNFORD: Were you going to say anything?

MR. CORUM: No. Well, are you done? I'll finish up.

MR. DUNFORD: Okay.

MEMBER KIRCHNER: Mike, can I ask you? Since you credit your stack height, are you designing that stack for the seismic and hurricane missile --

MR. CORUM: Yes.

MEMBER KIRCHNER: -- not hurricane, sorry, I misspoke, tornado missiles?

MR. CORUM: Yes. Yes, it will have to be designed. Yes.

MEMBER KIRCHNER: Okay, thank you.

MR. CORUM: And just to finish up on this slide, we talked a lot about seismic. We do understand that we have to address the higher frequencies above 10 hertz effect on equipment and electrical relays and things of that nature. So we will take that into account when we're doing our analysis.

The heavy snowfall and ice buildup, again, we'll look at the load to the roof, but also the impact to any SSCs that might be outside the primary facility.

MR. DUNFORD: Good.

MR. CORUM: Okay, it's yours.

MR. DUNFORD: Thanks, Michael. So the next six pages are --

MEMBER KIRCHNER: Small font.

MR. DUNFORD: -- small font, thank you. As we talked earlier, we had the 145, 140-ish PHA accidents that we bend that said needed further analysis, and then we did 75 as part of our quantitative risk assessment. So that's what these next six tables are.

The last column in the PHA said, this was an SC-01 or this was an SR-01 and it assigned a number to it. That number relates to the first column on Slide 41 where it says, PHA accident sequence number.

So SR-1, 2, 3, there should be 20. I think there is 28 of those. Oh, 32 of them. Yes, knew it was something like that, plus or minus two. There's 30 plus or minus two, I just didn't know which way it was.

And then the series of criticality or if it was a facility or a fire. That's what all these, the first column on these descriptors is. Or I mean on the sequence.

The next is a brief description of the event. The first, SR-01, 02, 03 are all sprays. SR-04 is liquid entering a, actually, SR-04 is the IRU loss of retention or loss of efficiency.

Anyway, and then this is what's been accredited or whether, it will also tell you that there's a sequence, as part of the QRA, that it did not come up to be, either as part of the further analysis, we decided the unlikely, it was, which one unlikely? Ten to the minus fifth.

MEMBER POWERS: Highly unlikely.

MR. DUNFORD: Highly unlikely, thank you. Or, as part of the evaluation, we'd say the consequences here are, again, below the thresholds for IROFS.

So that's what this table is doing. And this is obviously in Chapter 13. And I would entertain questions on the table. I'm not sure if there's a lot of benefit to going through each one of the individual line items. Going, going, going.

Okay, Page 47. And actually, I think it was talked a little bit about in the ISA, chemical accidents. So the next couple of slides should just be, two slides.

There is a QRA that looks at chemical hazards. There was some chemical hazard work done as part of the ER. And we still have some more work to do in this area.

The ER generates some chemical exposures that are kind of non-physical in nature, which were more than bounding for the ER. But we have chosen not to take the non-realistic accidents forward at this stage, into here.

So what we have in here are sample accidents and a nitric acid accident. And I think we did not discuss the sodium hydroxide accident that's in the ER example.

MEMBER POWERS: You don't need to, your dissolution proceeds smoothly without adding HF?

MR. DUNFORD: Yes. Definitely.

(Off microphone comment.)

MR. DUNFORD: Dissolution goes quickly without adding HF.

MEMBER POWERS: Sometimes uranium dioxide you've got to get a little hydrofluoric in there, with the nitrate, to get it to dissolve.

MR. DUNFORD: Well, you'll, in the nonpublic you'll see some of the work video, and it's --

(Off microphone comment.)

MR. DUNFORD: Yes. You'll be able to understand at least it's material, based on the process, prototypical to what we would do. The targets a little smaller volume, but the material that was dissolved was prototypical.

And Carolyn has quite a bit of data on that and we have seen no need for having to add a second acid.

So, chemical burns sample analysis, you're going to end up, and again, this is the discussion that has license material and a chemical hazard together. And there's also criticality controls, by the way, earlier on that I haven't talked about in some of the other analysis, that deal with proper containers and seismic containers and material being transferred into the laboratory and stuff.

So where we end up, from a chemical hazard, this first set is laboratory based sample analysis. And the second accident, which is the larger type of accident, is a, we have a fairly large nitric acid tank, and this is a breach of that tank and a leak of that tank. So we still have some work to do here.

The offsite looks like we're okay, but there's still the worker issue that we still have to work through, so there's still more work to be done in our chemical accident. So there's definitely some follow on work to do.

I guess I'll just leave it at that. But right now, we have not identified IROFS level controls with those systems, beyond lots of defense-in-depth standard and industry controls for the chemicals.

MEMBER POWERS: And nitric acid is one of the easier acids to handle.

MR. DUNFORD: Well, it is. And the evaluation that this was based on was, again, not exactly done by a chemist or a chemical engineer.

So we have inappropriate vapor pressures, which was fine, because it created a bounding accident for our ER, but we still have some work to do to update this in our, as part of the

FSAR.

CHAIR CHU: Thank you. I think I'm going to let the Staff come up and, thank you.

MR. BALAZIK: Good morning, again, this is Mike Balazik. This is Staff's presentation of Chapter 13.

And we have a new member up here, his name is Jim Hammelman and he did, from NMSS, and he did the review on the chemical side. So I just wanted to introduce him real quick, and we'll go ahead and start with the presentation.

MR. TITINSKY: Okay. As stated in earlier presentations, these are the regulatory requirements from Part 50 in the acceptance criteria that we've used before. So no reason to get into details there.

The accident analysis was, the purpose of it was for Northwest to identify and analyze accident scenarios that represent a range of credible scenarios in their facility.

Northwest has chosen to use the ISA methodology to demonstrate compliance with Part 50, as per the ISG augmenting NUREG-1527, based on the performance requirements of 70.61.

Next slide. These are the sections that are in Chapter 13. I'd like to note that Applicant would need to reevaluate accident scenarios and determine IROFS measures and defense-in-depth in the operating license application.

13.1, we've already gone over it, that was April's presentation. I'll be talking of 13.2 and Jim will be talking about 13.3.

And again, this is the objective. The Staff review is to determine, with reasonable assurance, that propose design is adequate at the construction permit stage and adequate preliminary IROFS to prevent or mitigate credible accidents with intermediate and high consequences were derived.

So in 13.2, the Staff evaluated technical information presented in the application, as supplemented by different various answers to request for additional information, to assess the efficiency of the accident analysis for issuance of a construction permit.

Section 13.2 is a summary discussion of events that have been identified using the ISA process, and also contained in the ISA summary that is submitted as part of the application.

Northwest Medical has identified credible events, likelihoods, consequences based on its preliminary design, using that methodology. It was derived from Part 70.

Next slide. So a little bit of a summary of the application. 13.2, the accents are laid out, structured in, sort of in families, which I'll talk about.

They talk about the credible RFA, accidents in the facility involving operations of irradiated target process, target material recycling and radioactive waste handling. As we've mentioned earlier, target fabrication was not part of the review of the construction permit.

Northwest also had assumed that postulated criticality accidents, or high consequent events, they presented quantitative estimates for dose consequences, from accident analysis to the public. Also, they were able to update those analysis and consequences as part of the operating license application.

They've also provided qualitative worker consequence estimates in the PSAR. They state that they'll also provide those in the final site analysis report as the design matures.

For the purpose of the construction permit, Northwest identified, based on, in preliminary information, the credible accidents that may result in intermediate high consequence derived from the performance of Directive 70.61. As per the methodology, events are assigned the likelihood category and the consequence level is determined.

Northwest has identified the likelihood categories for various types of events, which they have shown today from 13.2 of the PSAR. As appropriate, IROFS are developed for the event, management measures that will make the particular IROFS available.

Reliable will also be described in the operating license application. And the intent is to demonstrate compliance with the regulatory requirements.

The next two slides actually just cover the areas that are broken down to the various families. Which Northwest has discussed the spills and sprays, dissolver offgas, leaks into auxiliary systems, the loss of electrical power. And then actually the next slides are natural phenomena and other accidents,

So it should be noted that with respect to the methodology, indeed IROFS management measures -- by likelihood and consequences, by the event and not by the event type.

So even though these are sort of general categories, the actual ISA goes into individual events and breaks them down specifically into what particular IROFS are needed for particular systems. Not just in these general types of categories.

MEMBER BLEY: David?

MR. TITINSKY: Yes.

MEMBER BLEY: I skimmed through your slides, and Jim's too I guess, and you're going to go through a lot of detail on how well they did their analyses, which is important, I agree, and how they decided about IROFS and if there's are thorough.

Were you able, did you in some fashion, kind of look, in a global way, to convince yourselves that there isn't a class of event they've missed, that could be important? Which seems an important conclusion for you guys to draw at this point, before the construction permit.

MR. TITINSKY: Yes. There's really a couple parts to that. First is, these are just examples of particular events, obviously. And they go through all their ISA. There's the 75 plus events that they've identified.

So as part of the review, and it's not just me, I'm considered the spokesperson here for the Staff on this, but each of the individual reviewers, and Jim will talk a little about his particular one, but each individual reviewer is for the technical disciplines, went through their events that were related to that discipline to try and determine whether they agreed with whether they were covering the right events. We asked questions where appropriate.

So I think we have reasonable assurance that they are looking at the right things. Again, some things will kind of evolve. Obviously, there's going to be new events or changes to IROFS based on the final design.

But the Staff had not identified anything particular that had been left out, except I'll let Jim talk about his couple of things that he had actually asked about, which were sort of beyond what you had actually seen in the Northwest application.

MEMBER BLEY: Thank you.

MR. TITINSKY: Okay, the spills and sprays accidents. The following really just is a discussion of the various events, the examples of how Northwest has implemented its ISA methodology for specific event types.

The liquids sprays and, spills and sprays, the accident scenario. And this is, again, the broad family of accidents that they've laid out.

Liquid leaks and sprays involving dissolver product solution or uranium separation feed,

The product liquid stream is characterized by the bounding radionuclide stream concentrations that were provided.

The accident scenarios were process lined or vessel ruptures or leaks. Spraying, emptying contents of the hot cell or hot cell atmospheric exhaust to the environment with no filters active.

Next slide. So based on that, their accident likelihood, they determined was not unlikely. Again, go back to their charts, you kind of see where this fits in. They've identified the consequences to the worker is high.

And they mentioned here, to the public one, they'll calculate that in the FSAR.

So the spill and spray accidents have been assigned, by Northwest, a likelihood of Category 3 are not unlikely. Those definitions were provided, and April discussed them, and so has Northwest.

Northwest determined that they had a high radiological consequence to workers. It's should be noted that IROFS would be applied to these events to make them highly unlikely. Regardless of whether the receptor was to worker or the public.

So ISA is a little different on that. In fact, some applicants in other areas also, if they had difficulty determining the exact calculation of something like a dose, they can just say it is a high consequence event, declare it high consequence and provide IROFS for that.

So that's the reason why we think that's acceptable to come up with a, if they call it high consequence event then we know they're going to provide the IROFS and then manage their measures to mitigate that. Mitigate or prevent that.

Next slide. So continuing, so Northwest has identified IROFS for spill or spray accidents, sequences in order to make them highly unlikely.

The Table 13.4 of the PSAR, which is the radiological production facility risk matrix, was used to show that the combinations of likelihood and consequence that would be considered acceptable.

And a more detailed analysis of the consequence likelihood IROFS and manager measures were provided by Northwest and analyzed by the staff in the operating license application. Again, based on final design information.

So I mentioned these IROFS, I won't go into them again since Northwest has already kind of gone through those.

The next is the target offgas analysis. And again, their accident likelihood for this particular accident was not unlikely. For workers, they'll provide those details in the FSAR, but they have identified this as an intermediate consequence event for the public.

And again, the need to identify additional IROFS, based on worker doses, we'd expect to see that as part of the final application.

Again, the Staff finds that acceptable because they are demonstrating that they need to apply IROFS on the public, and we need to revise that later.

Next slide. So again, these are just the preliminary IROFS that are identified for the target offgas analysis. Again, to get into the details for the specific parts of the event, not just the general event of target offgas. They've gone through their PHA and provided their ISA summary.

Next slide. So the leaks into auxiliary systems. They provide information, a description of the accident analyses for that. Accident scenarios identified by a liquid solution leak into secondary containment, which could cause, again, radiological exposures or criticality events.

They also determine the likelihood here is not unlikely. The radiological consequences for workers is high. And also, the possibility of criticality, which is also a high consequence event.

So they've identified preliminary IROFS, both for the radiological part of this and criticality part of this, and yet we've had a lot of discussion of those so I won't get too much into details of those.

Next slide. So the loss of power. We've also talked about this quite a bit already today. So the likelihood for these events are not unlikely. And what Northwest has said here that no additional IROFS were identified, based on a specific event.

I guess in a way that could sound a little misleading. It's not that there are already IROFS that were related to loss of power events, it's just the way they've done their analysis. It just didn't add any more to the other events they already have.

So every event that we've identified, with intermediate high consequences that show in the table that required IROFS, they at least identify preliminary IROFS in their ISA summary and then in their application.

Next. So the Staff review of natural phenomena. So they've described natural phenomena events. Including the tornados, high winds, heavy rain, flooding, seismic heavy snowfall and ice buildup.

They've selected IROFS to prevent or mitigate events for some of them. For seismic, particularly, they identified the, in a radiated target cask lifting fixture.

What I'd like to note here, in the last bullet, that there are some high, what they call high consequence events that they identified under QRA is not provide, not meeting IROFS, based on the event frequencies. That's something that we'll focus on during the operating license application.

For instance, some cases, in seismic events, are a perfect thing. You may have an event that you call highly unlikely right away, but sometimes smaller earthquakes can provide, actually have impacts based on the internal equipment of how it performed. So it's something that has to be analyzed and were reviewed in the FSAR.

Next slide. So the other accidents, really, that's the compilation, is Northwest showed, the long list of the rest of accidents, and I won't go into those in particular.

Again, that they identified ones that are intermediate or high consequences are to prevent criticality, needed IROFS and will need management measures. And we expect to see an update in the FSAR.

So for this portion of the findings related to accidents, with radiological and criticality safety consequences, so the Staff evaluated sufficiency of the analysis and the selection of preliminary IROFS by reviewing the preliminary accident, accident scenarios, the results and the IROFS selected to prevent or mitigate the possible results.

The Applicant will update the worker and public quantitative safety consequences and likelihood in operating a license application.

The staff determined that the summary description of the accident analysis IROFS demonstrates adequate design bases for a preliminary design. And the Staff concludes that preliminary accident analysis is sufficient for issuance of a CP.

Additionally, it is subset selection of IROFS and management measures, should, with reasonable assurance, protect the health and safety of the public and workers.

Based on the reviews and examples of the implementation, the ISA methodology for accident with radiological and criticality and safety consequences, the staff has reasonable assurance that the Northwest ISA methodology is sufficient for issuance of a construction permit, and the staff will perform an detailed review of the implementation of the ISA methodology as part of the operating license review.

Next, I'll turn it over to --

MR. BALAZIK: Just one second. Sorry. Kathy, is the dedicated phone line open right now?

MS. WEAVER: It should be.

MR. BALAZIK: Yes? John Atchison, are you on the phone?

MR. ATCHISON: This is John Atchison. I'm on the phone.

MR. BALAZIK: Excellent. Dr. Bley, I'd like to ask John Atchison, who was a reviewer. Your question that you posed, I can do it, and correct me if I get it wrong, the one that you talked about for global review, did we identify by any class? John, I don't know if you heard the question earlier about Dr. Bley, and I just kind of wanted to ask you for your input. He had asked that, during our review, did we see any class or family of accident events that maybe Northwest missed? Do you have any thoughts on that?

MR. ATCHISON: This is John Atchison. The ISA did quite a thorough look at categorizing accidents. Within the review we performed at this stage, I did not come up with any unforeseen accidents that we address with RAIs.

MR. BALAZIK: Thanks, John.

MR. ATCHISON: That's not to say that, you know, it's certainly a possibility that could arise in the final review.

MR. BALAZIK: I understand. Thank you.

MEMBER KIRCHNER: Michael or David, can I ask kind of a process question? So it appears that -- well, maybe I should ask the question I want to ask. Did you do any bounding analyses of what the source terms would be to the public or the workers? It's a leading question because, you know, you kind of say that if they identify it as high consequence then you'll wait to the FSAR to take a quantitative look at what the applicant is proposing. This is a rhetorical question. Category 3 high consequence for off-site is 25 rem. What if, at the early stage, you got an application where they estimated the bounding dose was 100 rem? That's a higher than high consequence. Or maybe it's in a populated area? I'm just searching to see whether you just take what the applicant gave you and said that's reasonable, or did you do some estimates on your own to audit their preliminary assessment of high consequence to the public?

MR. TIKTINSKY: I'll answer a couple of ways. I think John Atchison answered the question about doing the, looking at the source term because I know they had looked at that.

The ISA methodology tells you that you have high consequence. It doesn't rate very high, ultra high. It's just high. And so when they've identified an event that's high and they need to mitigate or prevent it, they'll need to demonstrate that in case it's high and likely a category three that it comes down to low consequence. So they will need to demonstrate through their analysis that the IROFs that they have selected will actually mitigate or prevent that to get it down to the low consequence to make it acceptable.

So if it is something that was significantly high, they may need to require more controls to make it in that category, rather than something that may be was on the edge. But the way the methodology is, it just says high.

MEMBER KIRCHNER: Thank you.

MR. BALAZIK: John Atchison, is there anything you can share on the source term?

MR. ATCHISON: This is John Atchison with ISL. I think it was presented by Northwest Medical in their earlier presentation. They factored in a lot of conservatism in their source term calculation to cover uncertainties early in the design.

MR. HAMMELMAN: This is Jim Hammelman. I'm going to say, on the chemical side, I did do some independent checks of their calculations, but I looked at the source term that they used, too. So, you know, again, the purpose was to see if I was in the same ballpark as they were, and I did not see any on the chemical front, from a toxicity standpoint, any large disparity.

MEMBER KIRCHNER: Thank you.

MEMBER STETKAR: Before we switch gears to the chemical, I have a couple of comments on the SER. I noted differences in the bullets the way the information was presented here in the briefing compared to the way it's presented in the SER. And in particular, the staff makes statements such as the analyses that have been performed, ensure that no credible accident could lead to unacceptable radiological consequences to people or the environment.

That's actually not, that's a not-factual statement. I hate the term credible, but NWMI has quantitatively told us what not credible means. It means that it has a frequency of less than ten to the minus six per year. Indeed, there are many scenarios that they have evaluated that have frequencies above ten to the minus six per year, in particular between ten to the minus fifth and ten to the minus sixth, that do have high consequences. They only show that it is highly unlikely.

So they have many highly unlikely sequences that have really bad consequences. Those are credible sequences. So the staff is saying to the public that there are no credible sequences with unacceptable consequences. That's not factually correct. That's simply not correct within the construct that's been established in their quantitative analyses.

So I'd encourage the staff to go back through the SER and carefully look at every time you use the word credible and think that not credible means less than ten to the minus six. Anything above ten to the minus six is credible. It might be highly unlikely, but that's all they have to show.

MR. BALAZIK: Yes, sir. I appreciate that. I understand.

MEMBER STETKAR: The other thing that you didn't have on these bullets, and, as I said, the presentation this morning doesn't have these kind of trigger words in them, is that in many cases you say that you have assurance that the analyses, the preliminary analyses that they've done demonstrate acceptable risk. Well, risk is frequency and consequences. In Chapter 13, they have no information about frequency except this very broad thing of not unlikely or that sort of thing.

They've not actually quantified risk, so it's not clear to me how you can draw a conclusion at this stage of the game that their preliminary analyses have demonstrated --

MR. BALAZIK: From Chapter 13.

MEMBER STETKAR: From Chapter 13 or any of the reviews that they've done because they've told us they have not reviewed any of the quantitative analyses yet. So, again, also when you go back through the SER, look for terms like acceptable risk or risk and think carefully the context that those terms are used and the way the staff is presenting them. I did not see those terms in these bullets. These bullets are more carefully worded for this presentation than many parts of the SER. The SER provides, in my opinion, more confidence in the ultimate conclusion than it ought to, given the level of review and the level of sophistication of the analyses to support that review. So be careful about that, please.

MR. BALAZIK: Appreciate it. Thank you.

MR. HAMMELMAN: My name is Jim Hammelman, and I'm going to talk about the chemical safety review that I did. I'm a chemical engineer of a process, work in process areas, about 45 years' worth of experience in various areas.

I started with this Section 13.3, which is accident analysis with hazardous chemicals. But I took a broader view than that because I'm interested not only in the toxic hazards, but what I call the reactive hazards. And so we'll get a little more of that later on.

And the question I'm asking myself is have the hazards been recognized and then have they been accommodated in the design to date that we're seeing? And in some cases, I'm also asking the question are there R&D plans for addressing unresolved chemical safety issues?

So the next slide. These were sort of the steps in my review. I looked at review criteria and the performance objective. I did a pretty thorough review, I think, of the process, the process equipment, the facility design. I had to plow through a lot of information there to try and get an understanding that let me do some independent analysis.

I reviewed their accident analysis and the ISA summary. I went through each and every accident looking for is there a chemical safety aspect of it, either toxic material or a reactive hazard that could disperse either radiological or chemical toxic materials?

Then after I did that, I looked at the adequacy of the engineered safety features, and most of those were set up to mitigate a spectrum of accidents, including the ones that were chemical in nature. And then, finally, I evaluated the need for additional information for the FSAR.

Next slide. On the proposed design standards, Northwest had identified four ASTM standards that relate to the design of hot cells and equipment in hot cells, and I found those appropriate and acceptable. And they also committed to the performance requirement, not that they have demonstrated achievement of but they committed to meeting the performance requirement of 70.61, which means high consequence events are highly unlikely and intermediate consequences are unlikely. These standards and performance requirements I found to be acceptable.

In my review of the technology, I would characterize it as some of it is well known, well understood technology, and that includes the target dissolution and the off-gas system. And then some of the other stuff is there's less operational experience, and so you don't have that operational experience to draw upon, and I'm speaking there of the moly recovery and purification, as well as their specific system for uranium recovery and purification.

I do want to point out that the throughput, the scale of throughput for this operation is really quite small. If you just look at the size of the equipment, this is sometimes just a little bit larger than a high school chemistry bench scale. Some of it is a little bit bigger than that, but this is not large-scale industrial processing. That has some safety implications.

Next slide, please. As I said before, I did examine all the accident sequences in the PSAR and ISA, focusing on those that related to chemical safety.

MEMBER BLEY: We're going to have a session this afternoon where you can get into that.

MR. HAMMELMAN: So I performed some preliminary analysis on potential over-pressures given my understanding of material properties and volumes and locations of the material. It appeared to me that the facility can withstand these kind of over-pressures. So next slide. But we still asked some questions about these materials, trying to make sure that it's on the record and trying to make sure that Northwest addresses it for the FSAR. And maybe I won't read the slide if that is sensitive material.

MEMBER BLEY: We need to take a short break, about five or ten minutes. If you two can meet with Carolyn, if you can work this out. We'll recess for five minutes.

(Whereupon, the foregoing matter went off the record at 12:26 p.m. and went back on the record at 12:30 p.m.)

CHAIR CHU: We'll resume.

MR. HAMMELMAN: So for the FSAR, the things that I'm going to be looking for is re-examination, the things I'm going to be looking for in the FSAR is the re-examination of chemical safety, toxic as well as reactive, particularly re-examination of energetic hazards in light of any R&D that's been conducted and re-evaluate the engineered safety features in the IROFs.

On the last front, I might make the statement that the IROFs that have been identified are the engineered safety features and IROFs that have been identified so far are of a mitigative nature, and that's probably appropriate given the level of the design. But I would also be looking for preventive controls as the design progresses and the analysis becomes more detailed.

That concludes my remarks. Yes, they're yours now. Oh, okay. I'm sorry. There's nothing important here. We've covered it.

MEMBER REMPE: In the interactions between you and Northwest Medical Isotopes, there was some discussion about ongoing R&D to address some questions that you raised, and I know you guys are doing an Appendix A that you referenced in your draft SE that

I have a couple of questions about the whole thing. One, will we ever see Appendix A? And when will we see it? In our review?

MR. HAMMELMAN: That might be a Mike question. I do not know.

MEMBER REMPE: I'm sorry. Okay. So in the interactions with the RAIs, there was some R&D identified and, in your response or your discussion of it in Chapter 13, you said, hey, got an Appendix A we're working on that's going to identify or list all the R&D that we're expecting, and will ACRS ever see that appendix?

MR. BALAZIK: Yes. They have two items, one they've identified, and we plan on adding this one, too. But, yes, we are going to -- that will also have the table for action items, but it will also have the table for research and development.

MEMBER REMPE: Okay. So when will we see that? Like, we're having a meeting September 21st or something like that, and will it be ready for us --

MR. BALAZIK: It should be ready. What we have to do is capture a lot of the discussion here in that, not the R&D table but the other action items. That will take a little while, but, yes, I think we can get it to you for the September 21st meeting.

MEMBER REMPE: Okay. So there's always that 30-day advance thing that we have.

MR. BALAZIK: I know.

MEMBER REMPE: And then have you had any additional interactions with them about where they are in the R&D? And maybe this can be said in the closed session. I can read the transcript later. But, I mean, have you seen any of the results from it?

MR. BALAZIK: I have not, no.

MEMBER REMPE: Okay. I kind of got derailed with Ron's interesting story about how he cooks turkeys, but you're doing R&D to address some issues and have you completed it or where are you guys at on it?

MR. TIKTINSKY: Okay. So this is just sort of the overall evaluation findings for the entire Chapter 13, including Jim's stuff. So Northwest has analyzed a set of accidents that should be representative of the possible range of events that may occur in an operating production facility. Identified selection of preventative and mitigating preliminary IROFs. Further detailed technical design or analysis information may be reasonably left for later consideration in the FSAR to support operation of facility. Safety features which require R&D have been described and applicant will conduct an R&D program to resolve the safety questions and that there is reasonable assurance that proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of public and workers.

That's it for all the slides.

CHAIR CHU: Any questions? We're right on time, too. You know, according to the agenda, we're going to give members of the public an opportunity to make comments if there are any. First, I want to see if there are any public members in the audience. No. Any members of the public on the bridgeline who wish to make comment?

MR. BROWN: Bridge open.

CHAIR CHU: Yes?

MEMBER BLEY: It sounds like nobody is --

CHAIR CHU: Nobody. Okay.

MEMBER BLEY: -- stepping up.

CHAIR CHU: This is the end of our open session for today. After lunch, we're going to go into the closed session. So I would like to go around the table and see if there are members who wish to make a comment for the public record. Ron, you want to -- okay.

MEMBER SUNSERI: I appreciate all the presentation from staff and the Northwest. No further comments.

MEMBER SKILLMAN: I concur with Matt. Thank you to the team. No more comment.

MEMBER BLEY: I guess this is going to be on yesterday and today. I don't have anything from yesterday, but I think today's presentation, especially, well, on the ISA and on the permanent hazards analysis, when you get to some of the details, you might have some difficulties. But, overall, I think we've seen a pretty thorough job, and I appreciate what we saw this morning.

MEMBER STETKAR: I'll echo that. Again, I think this afternoon in closed session we'll discuss some details, but, from what I looked at for the preliminary hazards analysis and the quantitative analyses that were available to us, I was overall quite impressed with the amount of work that NWMI has done at this stage in the process to evaluate the facility. And I really appreciate you making that information available to us. Thank you.

MEMBER MARCH-LEUBA: I have nothing to add.

MEMBER KIRCHNER: I would just like to

concur that I think they've presented a fairly, that the applicant that is, a fairly comprehensive assessment of ISA, PHA, and Chapter 13, given the stage that they are at in the design process. So I thank all the presenters and the staff.

MEMBER BROWN: No additional comments.

MEMBER REMPE: I also don't have any additional comments, but I appreciate the presentations from the staff and NWMI, if I can learn to say that acronym, and their tolerance for the questions. I appreciate that. Thanks.

CHAIR CHU: And I want to thank all of you for giving us very comprehensive presentations today, and I also want to thank Jim. You know, I really appreciate the way you present your review. I thought it was very insightful, and I want to thank you. And this afternoon, at the end of today, we're going to go around the table and discuss what topics are we going to talk about in September, okay? It looks like we probably will have another subcommittee meeting.

MEMBER BLEY: Is there any part of that we should talk about in the open session? I'm not sure.

CHAIR CHU: I don't know at this point.

MEMBER BLEY: Okay. I think we'll just wait, and then we'll have a public announcement of that meeting and what will be there. Yes, I think that's fine, and I would close the open session, and then we'll open again in closed session.

CHAIR CHU: Okay. And then we're going to take a one -- sure.

MR. TIKTINSKY: I just want to clarify one thing from yesterday to just give a little more information because we were, you were asking questions related to the target fabrication facility and construction, and I answered without having the regs in front of me. And I mentioned 70.21(f) was a prior regulation that relates to when they could start construction related to environmental things, nine months after, prior to commencement of construction is what they talk about here.

But there's also an additional section in the regulations, 70.23(a)(7), so it's not only the nine-month period, but 70.23(a)(7) talks about that the director of NMSS must give approval to that before they can begin construction. And it also has a statement in 70.23(a)(7) that commencement of construction prior to conclusion is grounds for denial to possess and use special nuclear material in plant or facility. So I just want to make sure that it was clear that this and there may be other sources of regulation that relate to that that need to be addressed prior to the beginning of something that's construction that includes the Part 70 target fabrication facility.

MEMBER KIRCHNER: David, did you, for the record, state the status of the environmental review that's a prerequisite that then sets the time for the nine months? I know the answer to the question but --

MR. BALAZIK: The environmental review has been, has been issued for the Part 50.

MEMBER KIRCHNER: When?

MR. BALAZIK: It was issued -- the 10 CFR 50 environmental review -- oh, go ahead, Carolyn. Is there something you want to say?

MS. HAASS: No, go ahead and I'll follow up.

MR. BALAZIK: I believe it was issued in June of this year.

MS. HAASS: May.

MR. BALAZIK: May. Thanks.

MS. HAASS: I do want to say one thing about the environmental --

MR. BALAZIK: Carolyn --

MEMBER BLEY: Have the mike on.

Re-introduce yourself because you're not at the table.

MS. HAASS: Oh, Carolyn Haass. I do want to say the environmental impact statement reviewed both all activities of the facility, which was both Part 50 and 70. So it was done in initiation, you know, obviously, with this Part 50 application.

MEMBER BLEY: And, David, thank you for the clarification. I appreciate it.

MR. TIKTINSKY: Just to make sure because we want to be clear about the regulations. We'll recognize any IS's as issued, but 70.21(f) refers to an application, so an application is a Part 70 application, which we don't have. So just to be very clear that the requirements either have to be met here or demonstrated and requested, you know, for some type of exemption and granted by the NRC for that before any of these can be declared that they are met.

CHAIR CHU: Okay. We're going to take a one-hour lunch, coming back at 1:45 for our closed session.

(Whereupon, the above-entitled matter went off the record at 12:42 p.m.)

U.S. Nuclear Regulatory Commission
ACRS Subcommittee Review

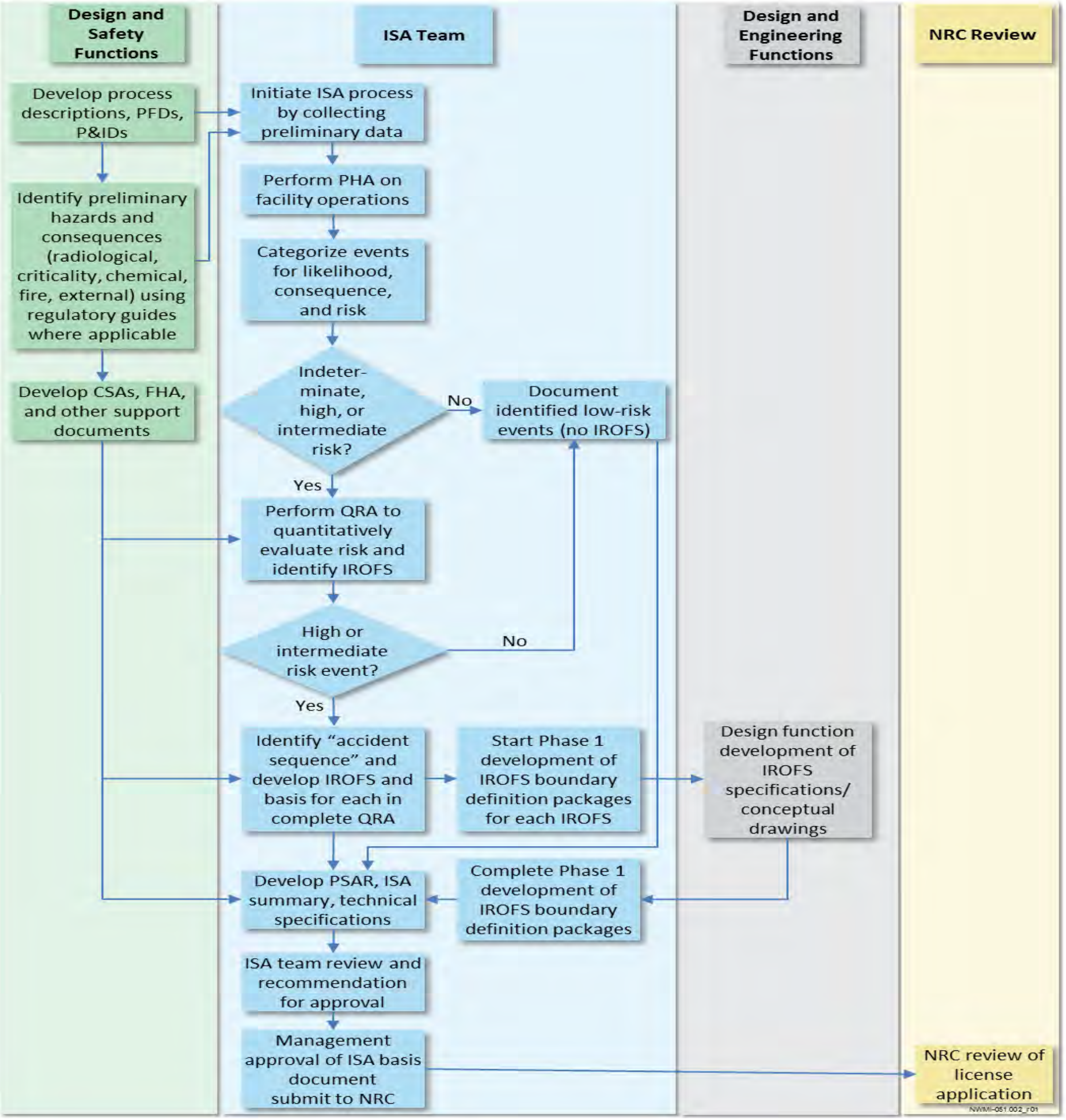
Integrated Safety Analysis

August 23, 2017

Integrated Safety Analysis

- NUREG-1537 requirements
  - Use of integrated safety analysis (ISA) methodologies (per 10 CFR Part 70, Subpart H, and NUREG-1520)
  - Application of radiological and chemical consequence and likelihood criteria contained in performance requirements of 10 CFR 70.61
  - Designation of items relied on for safety, and establishment of management measures are an acceptable way of demonstrating adequate safety for medical isotopes production facility
- ISA is a systematic examination of a facility's processes, equipment, structures, and personnel activities to ensure that all relevant hazards that could result in unacceptable consequences have been adequately evaluated and appropriate protective measures have been identified
  - Criticality safety evaluations (CSE) also provide a systematic examination of special nuclear material (SNM) processes, equipment, structures, and personnel activities to identify double-contingencies controls to maintain subcriticality

Integrated Safety Analysis Process Flow Diagram



Design and Safety Functions

Develop process descriptions, PFDs, P&IDs

Identify preliminary hazards and consequences (radiological, criticality, chemical, fire, external) using regulatory guides where applicable

Develop CSAs, FHA, and other support documents

ISA Team

Initiate ISA process by collecting preliminary data

Perform PHA on facility operations

Categorize events for likelihood, consequence, and risk

Indeterminate, high, or intermediate risk?

No

Document identified low-risk events (no IROFS)

Yes

Perform QRA to quantitatively evaluate risk and identify IROFS

High or intermediate risk event?

No

Yes

Identify "accident sequence" and develop IROFS and basis for each in complete QRA

Start Phase 1 development of IROFS boundary definition packages for each IROFS

Develop PSAR, ISA summary, technical specifications

Complete Phase 1 development of IROFS boundary definition packages

ISA team review and recommendation for approval

Management approval of ISA basis document submit to NRC

Design and Engineering Functions

Design function development of IROFS specifications/ conceptual drawings

NRC Review

NRC review of license application

NWMI-051.002_r01

Integrated Safety Analysis Methodology

- RPF was evaluated using an ISA process
  - Process hazards analysis (PHA)
  - Follow-on development and completion of quantitative risk assessments (QRA) to address events and hazards identified in PHA as requiring further evaluation
- Accident sequences were evaluated qualitatively to identify likelihood and severity using event frequencies and consequence categories consistent with regulatory guidelines
- Each event with an adverse consequence (involving licensed material or its byproducts) was evaluated for risk using a risk matrix that enables user(s) to identify unacceptable intermediate- and high-consequence risks
  - Items relied on for safety (IROFS) were developed to prevent or mitigate consequences of events
  - Risks were reduced to acceptable frequencies through preventive or mitigative IROFS
- Event trees analysis was used (certain circumstances)
  - Provided quantitative failure analysis data (failure frequencies)
  - Quantitatively analyzed an event from its basic initiators to demonstrate that quantitative failure frequencies are highly unlikely under normal standard industrial conditions (i.e., no IROFS required)
- Management measures were identified to ensure that IROFS failure frequency used in analysis was preserved and IROFS are able to perform intended function when needed
- Translation of IROFS (10 CFR Part 70) to technical specifications (10 CFR Part 50) will be developed

Consequence Severity Categories (Derived from 10 CFR 70.61)

Radioisotope Production Facility Consequence Severity Categories Derived from 10 CFR 70.61

Category description	Consequence category	Workers	Off-site public	Environment
High consequence	3	• Radiological dose[a] > 1 Sv (100 rem) • Airborne, radiologically contaminated nitric acid >170 ppm nitric acid (AEGL-3, 10-min exposure limit) • Unshielded[b] nuclear criticality	• Radiological dose[a] > 0.25 Sv (25 rem) • Toxic intake > 30 mg soluble U • Airborne, contaminated nitric acid > 24 ppm nitric acid (AEGL-2, 60-min exposure limit)	
Intermediate consequence	2	• Radiological dose[a] between 0.25 Sv (25 rem) and 1 Sv (100 rem) • Airborne, radiologically contaminated nitric acid > 43 ppm nitric acid (AEGL-2, 10-min exposure limit)	• Radiological dose[a] between 0.05 Sv (5 rem) and 0.25 Sv (25 rem) • Airborne, contaminated nitric acid > 0.16 ppm nitric acid (AEGL-1, 60-min exposure limit)	24-hr radioactive release > 5,000 × Table 2 of 10 CFR 20,[c] Appendix B
Low consequence	1	Accidents with lower radiological, chemical, and/or toxicological exposures than those above from licensed material and byproducts of licensed material	Accidents with lower radiological, chemical, and/or toxicological exposures than those above from licensed material and byproducts of licensed material	Radiological releases producing lower effects than those listed above from licensed material

Source: 10 CFR 70.61, "Performance Requirements," *Code of Federal Regulations*, Office of the Federal Register, as amended.

[a] As total effective dose equivalent.

[b] A shielded criticality accident is also considered a high-consequence event.

[c] 10 CFR 20, "Standards for Protection Against Radiation," *Code of Federal Regulations*, Office of the Federal Register, as amended.

AEGL = Acute Exposure Guideline Level.

U = uranium.

Likelihood Categories and Guidelines

Likelihood Categories

	Likelihood category	Event frequency limit
Not unlikely	3	More than 10^{-3} events per year
Unlikely	2	Between 10^{-3} and 10^{-5} events per year
Highly unlikely	1	Less than 10^{-5} per events per year

Qualitative Likelihood Category Guidelines

Likelihood category	Initiator
3	An event initiated by a human error
3	An event initiated by failure of a process system processing corrosive materials
3	An event initiated by a fire or explosion in areas where combustibles or flammable materials are present
3	An event initiated by failure of an active control system
3	A damaging seismic event
3	A damaging high wind event
3	A spill of material
3	A failure of a process variable monitored or unmonitored by a control system
3	A valve out of position or a valve that fails to seat and isolate
3	Most standard industrial component failures (valves, sensors, safety devices, gauges, etc.)
3	An adverse chemical reaction caused by improper quantities of reactants, out-of-date reactants, out-of-specification reaction environment, or wrong reactants are used
3	Most external man-made events (until confirmed using an approved method)
2	An event initiated by failure of a robust passive design feature with no significant internal or external challenges applied (e.g., spontaneous rupture of an all-welded dry nitrogen system pipe operating at or below design pressure in a clean, vibration-free environment)
1-2	An adverse chemical reaction when proper quantities of in-date chemicals are reacted in proper environment
1	Natural phenomenon such as tsunami, volcanos, and asteroids for RPF

Likelihood Categories and Risk Matrix

"Likelihood of an Occurrence" for each accident scenario will be based on:

- Frequency of initiating events
- Historic record of occurrence within similar systems
- Expert engineering judgment
- Assessment of number, type, independence, and observed failure history of designated IROFS

Likelihood Categories

	Likelihood category	Event frequency limit
Not unlikely	3	More than 10^{-3} events per year
Unlikely	2	Between 10^{-3} and 10^{-5} events per year
Highly unlikely	1	Less than 10^{-5} per events per year

Risk Matrix

Severity of Consequences	Likelihood of Occurrence Highly Unlikely (Likelihood Category 1)	 Unlikely (Likelihood Category 2)	 Not Unlikely (Likelihood Category 3)
High Consequence (Consequence Category 3)	Risk Index = 3 Acceptable Risk	Risk Index = 6 Unacceptable Risk	Risk Index = 9 Unacceptable Risk
Intermediate Consequence (Consequence Category 2)	Risk Index = 2 Acceptable Risk	Risk Index = 4 Acceptable Risk	Risk Index = 6 Unacceptable Risk
Low Consequence (Consequence Category 1)	Risk Index = 1 Acceptable Risk	Risk Index = 2 Acceptable Risk	Risk Index = 3 Acceptable Risk

Bounding Evaluations

- NWMI's ISA assumes a worst-case approach using a few bounding evaluations of events that are identified through either:
  - Calculations (e.g., source term and radiation doses caused by contained material in system)
  - Studies of representative accidents (e.g., comparison of accidental criticalities in industry with processes similar to those at RPF)
  - Bounding release calculations using approved methods (e.g., using RASCAL [Radiological Assessment System for Consequence Analysis] to model bounding facility releases that affect public)
  - Reference to nationally recognized safety organizations (e.g., use of Acute Exposure Guideline Levels [AEGL] from U.S. Environmental Protection Agency to identify chemical exposure limits for each consequence category)
  - Approved methods for evaluation of natural and man-made phenomenon and comparison to design basis (e.g., calculation of explosive damage potential from nearest railroad line on facility)

Initial Hazards

- Initial hazards identified by preliminary reviews include:
  - High radiation dose to workers and public from irradiated target material during processing
  - High radiation dose due to accidental nuclear criticality
  - Toxic uptake of licensed material by workers or public during processing or accidents
  - Fires and explosions associated with chemical reactions and use of combustible materials and flammable gases
  - Chemical exposures associated with chemicals used in processing irradiated target material
  - External events (both natural and man-made) that impact RPF operations

Accident-Initiating Events

- Criticality accident
- Loss of electrical power
- External events (meteorological, seismic, fire, flood)
- Critical equipment malfunction
- Operator error
- Facility fire (explosion is included in this category)
- Any other event potentially related to unique facility operations

PHA top-level accident sequence category	Definition
S.C.	Criticality
S.F.	Fire/Explosion
S.R.	Radiological
S.M.	Man-Made
S.N.	Natural Phenomena
S.CS.	Chemical Safety

Preliminary Hazard Analysis Results (continued)

Crosswalk of NUREG-1537 Part 1 ISG Accident Initiating Events versus RPF PHA Top-Level Accident Sequence Categories

NUREG-1537 Part 1 ISG Accident Initiating Event Category	PHA Top-Level Accident Sequence Category					
	S.C.	S.F.	S.R.	S.M.	S.N.	S.CS.
Criticality accident	✓	✓			✓	
Loss of electrical power			✓		✓	
External events (meteorological, seismic, fire, flood)	✓	✓		✓	✓	✓
Critical equipment malfunction	✓	✓	✓	✓		✓
Operator error	✓		✓	✓		✓
Facility fire (explosion is included in this category)		✓	✓			
Any other event potentially related to unique facility operations	✓		✓	✓		

[a] NUREG-1537, *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors – Format and Content*, Part 1, U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C., February 1996.

[b] PHA accident sequences involve one or more of NUREG-1537 Part 1 ISG accident initiating event categories, as noted by an ✓ in the corresponding table cell, but the PHA sequences themselves are not necessarily initiated by the ISG accident initiating event.

PHA = preliminary hazard analysis.

Process Hazard Analysis

- PHA (NWMI-2015-SAFETY-001) identifies and categorizes accident sequences that require further evaluation
- Completed PHA on eight "systems"; 107 nodes were evaluated
- Methodologies used:
  - HAZOP
  - What If
  - Event Tree
  - Fault Tree

Radioisotope Production Facility Preliminary Hazards Analysis
Primary Process Nodes and Subprocesses (2 pages)

Node no.	Node name	Subprocesses encompassed in node
1.0.0	Target fabrication process	• Fresh uranium receipt and storage • Fresh uranium dissolution • Uranyl nitrate blending and feed preparation • Nitrate extraction • Recycled uranyl nitrate concentration • [Proprietary Information] • [Proprietary Information] • [Proprietary Information] • [Proprietary Information] • [Proprietary Information] • [Proprietary Information] • Uranium scrap recovery • Target assembly, loading, inspection, quality checking, verification, packaging and storage
2.0.0	Target dissolution process	• [Proprietary Information] • [Proprietary Information] • Primary process offgas treatment • Fission gas retention
3.0.0	Molybdenum recovery and purification process	• Feed preparation • First stage recovery • First stage purification preparation • First stage purification • Second stage purification preparation • Second stage purification • Final purification adjustment • ^{99}Mo preparation for shipping
4.0.0	Uranium recovery and recycle process	• Impure uranium lag storage • First-cycle uranium recovery • Second-cycle uranium purification • Product uranium lag storage • Other support (storage vessels, transfer lines, solid waste handling for resin bed replacement)

Process Hazard Analysis (continued)

Radioisotope Production Facility Preliminary Hazards Analysis
Primary Process Nodes and Subprocesses (2 pages)

Node no.	Node name	Subprocesses encompassed in node
5.0.0	Waste handling system process	• Liquid waste storage • High dose liquid waste volume reduction • Condensate storage and recycling • Concentrated high dose liquid waste storage/preparation • Low dose liquid waste volume reduction and storage • Liquid waste solidification • Solid waste handling • Waste encapsulation • TCE solvent reclamation • Mixed waste accumulation
6.0.0	Target receipt and disassembly process	• Cask receipt and target unloading • Target Inspection • Target disassembly • [Proprietary Information] • Target disassembly stations • Gaseous fission product control • [Proprietary Information] • Empty target hardware handling
7.0.0	Ventilation system	• (No subprocesses identified in PHA. Ventilation system provides cascading pressure zones, a common air supply system with makeup air as necessary, heat recovery for preconditioning incoming air, and HEPA filtration.)
8.0.0	Natural phenomena, man-made external events, and other facility operations	• Natural phenomena • Man-made external events • Chemical storage and preparation areas • On-site vehicle operation • General storage, utilities, and maintenance activities • Laboratory operations • Hot cell support activities • Waste storage operations including packaging and shipment

^{99}Mo = molybdenum-99

HEPA = high-efficiency particulate air.

PHA = preliminary hazards analysis.

TCE = trichloroethylene.

Crosswalk PHA Process Nodes and Top-Level Accident Sequence Categories

Primary process node	PHA Top-Level Accident Sequence Category					
	S.C. (criticality)	S.F. (fire)	S.R. (radiological)	S.M. (man-made)	S.N. (natural phenomena)	S.CS. (chemical safety)
Target fabrication (Node 1.0.0)	✓	✓	✓			
Target dissolution (Node 2.0.0)	✓	✓	✓			
Molybdenum recovery and purification (Node 3.0.0)	✓	✓	✓			
Uranium recovery and recycle (Node 4.0.0)	✓	✓	✓			
Waste handling system (Node 5.0.0)	✓	✓	✓			
Target receipt and disassembly (Node 6.0.0)	✓		✓			
Ventilation system (Node 7.0.0)	✓	✓	✓			
Natural phenomena, man-made external events, and other facility operations (Node 8.0.0)	✓	✓	✓	✓	✓	✓

Note: The ✓ in a table cell indicates that the accident sequence category applies to the process node. If it does not, the cell is blank.

Qualitative Risk Assessments

- ~140 accident sequences were identified for additional evaluation
- 75 accident sequences were evaluated in QRAs
- 8 QRAs were completed, covering 75 accidents
- 1 QRA completed covering chemical accidents

Qualitative Risk Assessment Documents
Chemical Safety Process Upsets
Process Upsets Associated with Passive Engineering Controls Leading to Accidental Criticality Accident Sequences
Criticality Accident Sequences that Involve Uranium Entering a System Not Intended for Uranium Service
Criticality Accident Sequences that Involve High Uranium Content in Side Waste Stream
Facility Fires and Explosions Leading to Uncontrolled Release of Fissile Material, High- and Low-Dose Radionuclides
Radiological Accident Sequences in Confinement Boundaries (including Ventilation Systems)
Administratively Controlled Enrichment, Mass, Container Volume, and Interaction Limit Process Upsets Leading to Accidental Criticality Accident Sequences
Receipt and Shipping Events
Natural Phenomenon and Man-Made Events on Safety Features and Items Relied on for Safety

PHA Summary – Target Fabrication

Adverse Event Summary for Target Fabrication and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
1.1.1.1, 1.1.1.2, 1.6.1.1, 1.8.1.1, 1.8.2.1, and 1.8.3.1	Operator double batches allotted amount of material (fresh U, scrap U, [Proprietary Information], target batch) into one location or container during handling	Accidental criticality issue – Too much fissile mass in one location may become critical	S.C.02, Failure of administrative control on mass (batch limit) during handling of fresh U, scrap U, m[Proprietary Information], and targets
1.1.1.3	Supplier ships greater than 20 wt% ^{235}U to site	Accidental criticality issue – Too much ^{235}U put into a container or solution vessel, exceeding assumed amounts	S.C.01, Failure of site enrichment limit
1.1.1.6, 1.1.1.7, 1.6.1.2, 1.6.1.4, 1.8.1.2, 1.8.1.3, 1.8.1.6, 1.8.2.2, 1.8.2.3, 1.8.3.2, 1.8.3.3, 1.8.3.4, and 1.8.3.5	Operator handling various containers of uranium or batches of uranium components brings two containers or batches closer together than the approved interaction control distance	Accidental criticality issue – Too much uranium mass in one location	S.C.03, Failure of administrative control on interaction limit during handling of fresh U, scrap U, [Proprietary Information], and targets
1.2.1.1, 1.2.1.11, 1.2.1.14, 1.2.1.25, 1.3.1.1, 1.3.1.6, 1.3.1.11, 1.3.1.17, 1.4.1.19, 1.4.1.20, 1.4.1.21, 1.4.1.23, 1.4.2.6, 1.4.2.10, 1.4.2.15, 1.4.3.14, 1.4.3.26, 1.4.3.31, 1.4.4.1, 1.4.4.6, 1.4.4.10, 1.4.4.15, 1.5.1.21, 1.5.1.23, 1.5.1.26, 1.5.2.16, 1.7.1.1, 1.7.1.11, 1.7.1.14, 1.7.1.25, 1.9.1.1, 1.9.1.6, 1.9.1.10, and 1.9.1.15	Failure of safe geometry confinement	Accidental criticality from fissile solution not confined in safe geometry	S.C.04, Spill of fissile material from safe geometry system confinement
1.2.1.2 and 1.7.1.2	Uranium-containing solution leaks out of safe geometry confinement into the heating/cooling jacketed space	Accidental criticality from fissile solution not confined in safe geometry	S.C.05, Leak of fissile solution into heating/ cooling jacket on vessel
1.2.1.3, 1.4.3.33, 1.4.3.34, and 1.7.1.3	Uranium solution is transferred via a leak between the process system and the heater/cooling jackets or coils on a tank or in an exchanger	Accidental criticality from fissile solution not confined in safe geometry	S.C.07, Leak of fissile solution across auxiliary system boundary (chilled water or steam)
1.2.1.8, 1.3.1.4, 1.4.1.15, 1.4.2.4, 1.4.3.18, 1.4.4.4, 1.5.1.20, 1.5.2.11, 1.7.1.8, and 1.9.1.4	Failure of safe geometry dimension caused by configuration management (installation, maintenance), internal or external event	Accidental criticality from fissile solution not confined in safe geometry	S.C.19, Failure of passive design feature – Component safe geometry dimension
1.2.1.12, 1.3.1.9, 1.4.2.8, 1.4.4.8, 1.4.5.4, 1.7.1.12, and 1.9.1.8	Tank overflow into process ventilation system	Accidental criticality issue – Fissile solution entering a system not necessarily designed for fissile solutions	S.C.06, Overfill of a tank or component causing fissile solution entering the process vessel ventilation system

PHA Summary – Target Fabrication (continued)

Adverse Event Summary for Target Fabrication and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
1.2.1.12, 1.3.1.9, 1.4.2.8, 1.4.4.8, 1.4.5.4, 1.7.1.12, and 1.9.1.8	Tank overflow into process ventilation system	Accidental criticality issue – Fissile solution entering a system not necessarily designed for fissile solutions	S.C.06, Overfill of a tank or component causing fissile solution entering the process vessel ventilation system
1.3.1.2, 1.4.2.2, 1.4.4.2, and 1.9.1.20	Uranium precipitate or other high uranium solids accumulate in safe geometry vessel	Accidental criticality from fissile solution not confined to safe geometry and interaction controls within allowable concentrations	S.C.20, Failure of concentration limits – Precipitation of uranium in safe geometry tank
1.2.1.26, 1.3.1.7, 1.5.1.3, and 1.5.2.5	Uranium solution backflows into an auxiliary support system (water line, purge line, chemical addition line) due to various causes	Accidental criticality issue – Fissile solution entering a system not necessarily designed for fissile solutions	S.C.08, Fissile solution backflow into an auxiliary system at a fill point boundary
1.4.1.6, 1.4.1.12, and 1.4.1.16	Failure of safe geometry confinement due to inadvertent transfer to U-bearing solution across a boundary into non-favorable geometry	Accidental criticality from fissile solution not confined in safe geometry	S.C.11, Fissile material contamination of contactor regeneration aqueous waste stream - boundary to unsafe geometry system
1.4.3.1, 1.4.3.9, 1.4.3.19, 1.4.3.21, 1.4.5.9, and 1.4.5.11	Failure of safe geometry confinement due to inadvertent transfer to U-bearing solution across a boundary into non-favorable geometry	Accidental criticality from fissile solution not confined in safe geometry	S.C.09, Fissile material contamination of evaporator condensate - boundary to unsafe geometry system
1.6.1.3	Failure of safe geometry confinement due to inadvertent transfer to U-bearing solution across a boundary into non-favorable geometry	Accidental criticality from fissile solution not confined in safe geometry	S.C.12, Wash of [Proprietary Information] with wrong reagent contaminating wash solution with fissile U; boundary to unsafe geometry system
1.1.1.11	Dusty surface generated during shipping on uranium pieces spontaneously ignites due to pyrophoric nature of uranium	Potential exposure to workers due to airborne uranium generation	S.F.01, Pyrophoric fire in uranium metal
1.2.1.6, 1.2.1.11, 1.7.1.6, and 1.7.1.11	Hydrogen buildup in tanks or system, leading to explosive concentrations	Explosion leading to radiological and criticality concerns	S.F.02, Accumulation of flammable gas in tanks or systems
1.4.1.17, 1.4.1.21, and 1.4.1.23	Fire in process system containing high concentration uranium spreads the uranium	Radiological and criticality issue – Radiological airborne release of uranium and uncontrolled spread of uranium outside safe geometry confinement	S.F.07, Fire in nitrate extraction system - flammable solvent with uranium

PHA Summary – Target Fabrication (continued)

Adverse Event Summary for Target Fabrication and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
1.6.1.6, 1.6.1.9, and 1.6.1.12	Air inleakage into the reduction furnace during H_2 purge cycle or H_2 inleakage into reduction furnace before inerting with nitrogen can lead to an explosive mixture in the presence of an ignition source	Accidental criticality issue – Uncontrolled spread of uranium outside safe geometry confinement	S.F.03, Hydrogen detonation in reduction furnace
1.6.1.8	Loss of cooling of exhaust or fire in the reduction furnace leads to high temperatures in downstream ventilation component and accelerated release of adsorb radionuclides	Radiological issue – Potential accelerated release of high-dose radionuclides to the stack (worker and public exposure)	S.F.04, High temperature damage to process ventilation system due to loss of cooling in reduction furnace exhaust or fire in reduction furnace
1.2.1.11, 1.2.1.14, 1.4.1.17, 1.4.1.19, 1.4.1.20, 1.4.1.21, 1.4.1.23, 1.4.2.6, 1.4.3.14, 1.4.3.26, 1.4.3.31, 1.4.3.32, 1.7.1.11, 1.7.1.14, and 1.9.1.6	High concentration uranium solution is sprayed from the system, causing high airborne radioactivity	Radiological release of uranium solution spray that remains suspended in the air, exposing workers or the public	S.R.03, Solution spray release potentially creating airborne uranium above DAC limits
1.2.1.11, 1.2.1.12, 1.2.1.14, 1.2.1.25, 1.3.1.1, 1.3.1.6, 1.3.1.11, 1.3.1.17, 1.4.1.17, 1.4.1.18, 1.4.1.19, 1.4.1.21, 1.4.2.1, 1.4.2.6, 1.4.2.8, 1.4.2.10, 1.4.2.15, 1.4.3.14, 1.4.3.26, 1.4.3.31, 1.4.4.6, 1.4.4.10, 1.4.4.15, 1.5.1.21, 1.7.1.11, 1.7.1.14, 1.7.1.25, 1.9.1.1, 1.9.1.6, 1.9.1.8, 1.9.1.10, and 1.9.1.15	High concentration uranium solution is spilled from the system	Potential radiological exposure to workers from uranium-contaminated solution	S.R.01, Uranium-contaminated solution spill
1.2.1.21, 1.2.1.22, 1.4.5.13, 1.7.1.21, and 1.7.1.22	Boiling or carryover of steam or high concentration water vapor into the primary ventilation system, affecting retention beds from partial or complete loss of cooling system capabilities	Radiological release from retention beds	S.R.04, Liquid enters process vessel ventilation system damaging IRU or retention beds releasing retained radionuclides
1.3.1.16 and 1.4.1.24	High-dose solution (failure of the uranium recovery process) results in high-dose radionuclides entering the first stage of processing uranium [Proprietary Information] (eventually handled by the worker)	Potentially high radiological exposure to workers	S.R.05, High-dose solution enters the UN blending and storage tank
1.8.3.7	Loading limits are not adhered to by the operators or the closure requirements are not satisfied, and the cask does not provide the containment or shielding function that it is designed to perform	High-dose to workers or the public from improperly shielded cask	S.R.28, Target or waste shipping cask not loaded or secured according to procedure, leading to personnel exposure

PHA Summary – Target Dissolution

Adverse Event Summary for Target Dissolution and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
2.1.1.1, 2.1.1.11, 2.1.1.13, 2.1.1.17, 2.2.1.5, 2.2.1.12, 2.2.1.15, 2.3.6.5, 2.3.6.12, and 2.3.6.13	Failure of safe geometry confinement	Accidental criticality from fissile solution not confined in safe geometry	S.C.04, Failure of confinement in safe geometry; spill of fissile material solution
2.1.1.2	Uranium-containing solution leaks out of safe geometry confinement into the heating/cooling jacketed space	Accidental criticality from fissile solution not confined in safe geometry	S.C.05, Leak of fissile solution in to heating/cooling jacket on vessel
2.1.1.3	Uranium solution is transferred via a leak between the process system and the heater/cooling jackets or coils on a tank or in an exchanger	Accidental criticality from fissile solution not confined in safe geometry	S.C.07, Leak of fissile solution across auxiliary system boundary (chilled water or steam)
2.1.1.8, 2.2.1.11, and 2.3.6.11	Failure of safe geometry dimension	Accidental criticality from fissile solution not confined in safe geometry	S.C.19, Failure of passive design feature; component safe-geometry dimension
2.1.1.12, 2.1.1.15, and 2.3.1.4	Failure of safe-geometry confinement	Accidental criticality from fissile solution not confined in safe geometry	S.C.13, Fissile solution enters the NO_x scrubber where high uranium solution is not intended
2.1.1.14 and 2.3.4.14	Tank overflow into process ventilation system	Accidental criticality issue – Fissile solution entering a system not necessarily designed for fissile solutions	S.C.06, System overflow to process ventilation involving fissile material
2.3.4.11	Uranium enters carbon retention bed dryer where it can mix with condensate to form a fissile solution	Accidental criticality from fissile material or solution not confined in safe geometry	S.C.24, Build-up of high uranium particulate in the carbon retention bed dryer system

PHA Summary – Target Dissolution (continued)

Adverse Event Summary for Target Dissolution and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
2.1.1.33 and 2.1.1.34	Uranium solution backflows into an auxiliary support system (water line, purge line, chemical addition line) due to various causes	Accidental criticality and high radiological dose – High-dose and fissile solution entering a system not necessarily designed for fissile solutions that exist outside of hot cell walls	S.C.08, System backflow into auxiliary support system
2.1.1.18, 2.3.1.21, 2.3.2.21, 2.3.3.24, 2.3.4.3, and 2.3.5.5	Hydrogen build-up in tanks or system leading to explosive concentrations	Explosion leading to radiological and criticality concerns	S.F.02, Accumulation of flammable gas in tanks or systems
2.3.4.20, 2.3.5.2, 2.3.5.6, 2.3.5.10, and 2.3.5.13	A fire develops through exothermic reaction to contaminants in the carbon retention bed and rapidly releases accumulated gaseous high-dose radionuclides	Radiological issue – Potential accelerated release of high-dose radionuclides to the stack (worker and public exposure)	S.F.05, Fire in a carbon retention bed
2.1.1.1, 2.1.1.2, 2.1.1.11, 2.1.1.13, 2.1.1.17, 2.2.1.5, 2.2.1.12, 2.2.1.15, 2.3.6.5, 2.3.6.12, and 2.3.6.13	High-dose and/or high-concentration uranium solution is spilled from the system	Potential radiological exposure to workers from high-dose and/or high uranium-contaminated solution	S.R.01, Radiological release in the form of a liquid spill of high-dose and/or high uranium concentration solution
2.1.1.3	High-dose solution is transferred via a leak between the process system and the heater/cooling jackets or coils on a tank or in an exchanger	Radiological exposure to workers and the public from high-radiological dose not contained in the hot cell containment or confinement boundary	S.R.13, High-dose solution leaks to chilled water or steam condensate system
2.1.1.11, 2.1.1.17, 2.2.1.15, and 2.3.6.13	Spill leading to spray-type release, causing airborne radioactivity above DAC limits for exposure	Radiological dose from airborne spray of product solution from systems	S.R.03, Spray of product solution in hot cell area
2.1.1.23, 2.1.1.26, 2.1.1.27, 2.3.4.1, 2.3.4.12, and 2.3.4.17	Carryover of high vapor content gases or entrance of solutions into the process ventilation header can cause poor performance of the retention bed materials and release radionuclides	High airborne radionuclide release, affecting workers and the public	S.R.04, Carryover of heavy vapor or solution into the process ventilation header causes downstream failure of retention bed, releasing radionuclides

PHA Summary – Target Dissolution (continued)

Adverse Event Summary for Target Dissolution and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
2.3.1.17, 2.3.1.22, 2.3.1.24, 2.3.2.17, 2.3.2.22, 2.3.2.24, 2.3.3.8, 2.3.3.20, 2.3.3.27, 2.3.4.3, 2.3.4.5, 2.3.4.6, and 2.3.4.8	A spill of low-dose condensate occurs for a variety of reasons from the confinement tanks or vessels	Potential radiological dose to workers and the public from spilled liquid	S.R.02, Spill of low-dose condensate
2.3.3.1, 2.3.3.2, 2.3.3.3, 2.3.3.6, 2.3.3.12, 2.3.3.13, 2.3.3.16, 2.3.3.17, 2.3.3.23, 2.3.4.13, 2,3.5.1, 2.3.5.6, 2.3.5.8, and 2.3.5.10	High flows through the IRU increases the release of the retained iodine and increases the high-dose concentration of this gas in the stack	Potential radiological dose to workers and the public from iodine above regulatory limits	S.R.06, High flow through IRU causes premature release of high-dose iodine gas
2.3.3.15 and 2.3.5.8	Low temperatures in the IRU inlet gas stream drives release of iodine from the unit	Potential radiological dose to workers and the public from iodine above regulatory limits	S.R.07, Loss of temperature control on the IRU leads to premature release of high-dose iodine
2.3.3.22 and 2.3.5.8	Liquid and water vapor in the IRU inlet gas stream drives release of iodine from the unit	Potential radiological dose to workers and the public from iodine above regulatory limits	S.R.04, Liquid/high vapor in the IRU leads to premature release of high-dose iodine
2.3.4.4, 2.3.4.5, and 2.3.4.6	Loss of vacuum pumps in the dissolver offgas treatment system leads to pressure buildup inside the process and potential release of radionuclides from the system upstream	Potential radiological dose to workers and the public from spilled liquid	S.R.08, Loss of vacuum pumps
2.3.4.11	Uncontrolled loss of media and contact with a liquid with potential for premature release of the adsorbed iodine	Potential radiological dose to workers and the public from iodine above regulatory limits	S.R.09, Loss of IRU media to downstream dryer

PHA Summary – Target Dissolution (continued)

Adverse Event Summary for Target Dissolution and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
2.3.3.28, 2.3.4.19, 2.3.5.9, 2.3.4.15, and 2.3.5.11	Using the wrong retention media (IRU or carbon beds) or using saturated media with potential for ineffective adsorption of high-dose gaseous radionuclides	Potential radiological dose to workers and the public from radionuclides above regulatory limits	S.R.10, Wrong retention media added to bed or saturated retention media
2.3.4.16, 2.3.5.5, and 2.3.5.12	An event causes damage to the structure holding the retention media, and retention media is released to an uncontrolled environment	Potential radiological dose to workers and the public from radionuclides above regulatory limits	S.R.09, Breach of an IRU or retention bed resulting in release of the media
2.1.1.33 and 2.1.1.34	High-dose process solution backflows into an auxiliary support system (water line, purge line, chemical addition line) due to various causes	High radiological dose – High dose process solution enters a system that exits outside of the hot cell walls	S.R.11, System backflow of high-dose solution into an auxiliary support system and outside the hot cell boundary

PHA Summary – Mo-99 Recovery

Adverse Event Summary for Molybdenum Recovery and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
3.3.1.24	Higher radiation dose due to hold-up accumulation or transient batch differences	Higher localized dose in hot cell boundary (unoccupied by workers)	N/A
3.2.3.7, 3.2.4.7, 3.4.3.7, 3.4.4.7, 3.6.3.7, and 3.6.4.7	Chemical spills of nonradiologically contaminated bulk chemicals	Standard industrial accident – Chemical exposure (not involving licensed material) to workers	N/A
3.7.4.5 and 3.7.4.6	Dropped cask or cask component during loading or handling	Standard industrial accident – Worker injury	N/A
3.7.4.2, 3.7.5.2, and 3.7.5.3	Mo product is exposed with no shielding as the result of an accident, shipment mishap, or shipment mishandling after leaving the site	Potential dose to the public and/or environment due to release or mishandling of Mo product during transit	N/A – Addressed by DOT packaging and transportation regulations (10 CFR 71[a])
3.1.1.9, 3.1.1.14, 3.1.1.23, 3.1.2.4, 3.1.2.7, 3.1.2.13, 3.1.2.16, 3.1.2.17, 3.2.1.6, 3.2.1.10, 3.2.1.20, 3.2.1.22, 3.2.1.23, 3.2.2.9, 3.2.2.13, 3.2.3.6, 3.2.3.8, 3.2.5.9, 3.2.5.14, 3.2.5.23, 3.8.1.9, 3.8.1.13, and 3.8.1.22	Failure of safe-geometry confinement	Accidental criticality from fissile solution not confined in safe geometry	S.C.04, Failure of confinement in safe geometry; spill of fissile material solution
3.1.1.4, 3.1.1.16, 3.2.5.4, 3.2.5.16, and 3.8.1.4	Tank overflow into process ventilation system	Accidental criticality issue – Fissile solution entering a system not necessarly designed for fissile solutions	S.C.06, System overflow to process ventilation involving fissile material
3.1.1.23, 3.2.1.23, 3.2.5.23, and 3.8.1.22	Uranium solution is transferred via a leak between the process system and the heater/cooling jackets or coils on a tank or in an exchanger	Accidental criticality from fissile solution not confined in safe geometry	S.C.07, Leak of fissile solution across auxiliary system boundary (chilled water or steam)
3.2.1.4, 3.2.1.5, 3.2.2.3, 3.2.2.4, 3.2.2.5, 3.2.3.6, and 3.2.4.6	Fissile product solution transferred to a system not designed for safe-geometry confinement	Criticality safety issue – Fissile solution directed to a system not intended for fissile solution	S.C.10, Inadvertent transfer of solution to a system not designed for fissile solutions

PHA Summary – Mo-99 Recovery (continued)

Adverse Event Summary for Molybdenum Recovery and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
3.1.1.13, 3.1.2.9, 3.2.1.15, 3.2.5.13, and 3.8.1.12	Failure of safe-geometry dimension	Accidental criticality from fissile solution not confined in safe geometry	S.C.19, Failure of passive design feature; component safe-geometry dimension
3.1.1.25, 3.2.5.25, 3.3.1.25, 3.5.1.25, and 3.8.1.24	Hydrogen buildup in tanks or system, leading to explosive concentrations	Explosion leading to radiological and criticality concerns	S.F.02, Accumulation of flammable gas in tanks or systems
3.7.1.1, 3.7.1.2, 3.7.2.1, 3.7.3.1, 3.7.3.2, and 3.7.4.1	Operator spills Mo product solution during remote handling operations	Radiological spill of high-dose Mo solution	S.R.01, Radiological spill of Mo product during remote handling
3.1.1.9, 3.1.1.14, 3.1.1.23, 3.1.2.7, 3.1.2.13, 3.1.2.16, 3.1.2.17, 3.2.1.6, 3.2.1.20, 3.2.1.22, 3.2.1.23, 3.2.2.7, 3.2.2.9, 3.2.2.13, 3.2.3.6, 3.2.3.8, 3.2.3.10, 3.2.4.10, 3.2.5.9, 3.2.5.14, 3.2.5.23, 3.3.1.9, 3.3.1.14, 3.3.1.18, 3.3.1.22, 3.3.1.23, 3.3.2.4, 3.3.2.7, 3.3.2.13, 3.3.2.16, 3.3.2.17, 3.4.1.5, 3.4.1.9, 3.4.1.19, 3.4.1.21, 3.4.1.22, 3.4.2.6, 3.4.2.7, 3.4.2.12, 3.4.3.6, 3.4.3.8, 3.4.3.10, 3.4.3.14, 3.4.4.6, 3.4.4.10, 3.4.4.14, 3.5.1.9, 3.5.1.14, 3.5.1.16, 3.5.1.23, 3.5.2.4, 3.5.2.7, 3.5.2.13, 3.5.2.16, 3.5.2.17, 3.6.1.5, 3.6.1.6, 3.6.1.10, 3.6.1.20, 3.6.1.20, 3.6.1.23, 3.6.2.7, 3.6.2.9, 3.6.2.13, 3.6.3.8, 3.6.3.10, 3.6.3.14, 3.6.4.10, 3.6.4.14, 3.8.1.9, 3.8.1.13, and 3.8.1.22	Spill of product solution in the hot cell area	Radiological dose from spill of product solution from systems	S.R.01, Spill of product solution in hot cell area

PHA Summary – Mo-99 Recovery (continued)

Adverse Event Summary for Molybdenum Recovery and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
3.1.1.9, 3.2.1.10, 3.2.1.22, 3.2.2.7, 3.2.2.9, 3.2.3.8, 3.2.3.10, 3.2.4.10, 3.2.5.9, 3.3.1.9, 3.3.1.18, 3.3.1.22, 3.3.2.7, 3.4.1.10, 3.4.1.22, 3.4.2.7, 3.4.3.8, 3.5.1.9, 3.5.1.23, 3.6.1.10, 3.6.2.7, 3.6.3.8, and 3.8.1.9	Spill leading to spray-type release, causing airborne radioactivity above DAC limits for exposure	Radiological dose from airborne spray of product solution from systems	S.R.03, Spray of product solution in hot cell area
3.1.1.7, 3.1.1.22, 3.2.5.7, 3.2.5.22, 3.3.1.4, 3.3.1.7, 3.3.1.16, 3.5.1.4, 3.5.1.7, 3.5.1.16, 3.5.1.22, 3.8.1.7, and 3.8.1.13	Boiling or carryover of steam or high-concentration water vapor into the primary process offgas ventilation system affecting retention beds with partial or complete loss of cooling system capabilities	Radiological release from retention beds	S.R.04, Loss of cooling, leading to liquid or steam carryover into the primary offgas treatment train
3.7.4.3	A Mo product cask is removed from the hot cell boundary with improper shield plug installation	Potential dose to workers, the public, and/or environment due to release or mishandling of Mo product during transit	S.R.12, Mo product is released during shipment
3.3.1.23, 3.3.2.16, 3.4.1.22, 3.5.1.23, and 3.6.1.23	High-dose radionuclide solution leaks through an interface between the process system and a heating/cooling jacket coil into a secondary system (e.g., chilled water or steam condensate) releasing radionuclides to workers, the public, and environment	High-dose radionuclide solution that leaks to the environment through another system to expose workers or the public	S.R.13, High dose radionuclide containing solution leaks to chilled water or steam condensate system

[a] 10 CFR 71, "Packaging and Transportation of Radioactive Material," *Code of Federal Regulations*, Office of the Federal Register, as amended.

PHA Summary – Uranium Recovery and Recycle

Adverse Event Summary for Uranium Recovery and Identification of Accident Sequences Needing Further Evaluation (4 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
4.1.1.4, 4.1.1.18, 4.2.1.4, 4.2.1.6, 4.2.1.17, 4.2.1.18, 4.2.3.6, 4.2.8.4, 4.2.8.18, 4.2.10.4, 4.3.1.4, 4.3.1.6, 4.3.1.18, 4.3.1.19, 4.3.3.6, 4.3.8.4, 4.3.8.18, 4.3.10.4, 4.4.1.4, 4.4.1.17, 4.5.1.4, 4.5.1.17, 4.5.2.4, 4.5.2.17, 4.5.3.4, and 4.5.3.14	Tank overflow into process ventilation system	Accidental criticality issue – Fissile solution enters a system not necessarily designed for fissile solutions	S.C.06, System overflow to process ventilation involving fissile material
4.1.1.6, 4.2.1.7, 4.2.2.4, 4.2.3.4, 4.2.3.7, 4.2.3.8, 4.2.8.7, 4.3.1.7, 4.3.2.4, 4.3.3.4, 4.3.3.7, 4.3.3.8, 4.3.8.7, 4.4.1.6, 4.5.2.6, and 4.5.3.6	Uranium solution backflows into an auxiliary support system (water line, purge line, chemical addition line) due to various causes	Accidental criticality issue – Fissile solution enters a system not necessarily designed for fissile solutions	S.C.08, System backflow into auxiliary support system
4.1.1.14, 4.2.1.14, 4.2.3.16, 4.2.8.15, 4.3.1.15, 4.3.3.16, 4.3.8.15, 4.3.9.20, 4.4.1.14, 4.5.1.14, 4.5.2.14, and 4.5.3.11	Failure of safe geometry dimension caused by configuration management (installation, maintenance) or external event	Accidental criticality from fissile solution not confined in safe geometry	S.C.19, Failure of passive design feature; component safe-geometry dimension
4.1.1.8, 4.1.1.9, 4.1.1.12, 4.1.1.13, 4.1.1.16, 4.2.1.9, 4.2.1.13, 4.2.5.11, 4.2.8.10, 4.2.8.13, 4.2.8.14, 4.2.8.17, 4.2.9.18, 4.3.1.10, 4.3.1.11, 4.3.1.14, 4.3.1.17, 4.3.1.18, 4.3.5.11, 4.2.8.10, 4.3.8.13, 4.3.8.14, 4.3.8.17, 4.3.9.18, 4.4.1.8, 4.4.1.9, 4.4.1.12, 4.4.1.13, 4.4.1.16, 4.5.1.16, 4.5.2.8, 4.5.2.9, 4.5.2.12, 4.5.2.13, and 4.5.2.16	Uranium precipitate or other high uranium solids accumulate in safe-geometry vessel	Accidental criticality from fissile solution not confined to safe geometry and interaction controls within allowable concentrations	S.C.20, Failure of concentration limits
4.1.1.10, 4.1.1.15, 4.1.1.23, 4.2.1.11, 4.2.1.15, 4.2.1.24, 4.2.2.1, 4.2.3.11, 4.2.3.13, 4.2.3.18, 4.2.3.22, 4.2.3.23, 4.2.3.24, 4.2.4.10, 4.2.5.10, 4.2.7.8, 4.2.8.11, 4.2.8.16, 4.2.8.23, 4.2.9.16, 4.2.9.29, 4.2.9.34, 4.3.1.12, 4.3.1.16, 4.3.1.25, 4.3.2.1, 4.3.3.11, 4.3.3.13, 4.3.3.18, 4.3.3.22, 4.3.3.23, 4.3.3.24, 4.3.4.10, 4.3.5.10, 4.3.7.8, 4.3.8.11, 4.3.8.16, 4.3.8.23, 4.3.9.16, 4.3.9.28, 4.3.9.34, 4.4.1.10, 4.4.1.15, 4.4.1.23, 4.5.1.23, 4.5.2.10, 4.5.2.15, 4.5.2.23, 4.5.3.8, 4.5.3.12, and 4.5.3.19	Failure of safe-geometry confinement due to spill of uranium solution from the system	Accidental criticality from fissile solution not confined in safe geometry	S.C.04, Failure of confinement in safe geometry; spill of fissile material solution

PHA Summary – Uranium Recovery and Recycle (continued)

Adverse Event Summary for Uranium Recovery and Identification of Accident Sequences Needing Further Evaluation (4 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
4.2.3.21, 4.2.4.11, 4.2.6.12, 4.3.3.21, 4.3.4.11, and 4.3.6.12	Failure of safe-geometry confinement due to inadvertent transfer to U-bearing resin to the U IX waste collection tanks through a broken retention element	Accidental criticality from fissile solution not confined in safe geometry	S.C.14, Failure of confinement in safe geometry; transfer of U-bearing resin to U IX waste collection tanks
4.2.5.5, 4.3.1.9, 4.3.5.5, and 4.5.1.5	Failure of safe-geometry confinement due to inadvertent transfer to U-bearing solution to the U IX waste collection tanks	Accidental criticality from fissile solution not confined in safe geometry	S.C.14, Failure of confinement in safe geometry; transfer of U-bearing solution to U IX waste collection tanks
4.2.7.7, 4.3.7.7, and 4.5.3.10	Inadvertent transfer of high uranium-concentration solution or resins to spent resin tanks	Accidental criticality too high of uranium mass in waste stream	S.C.15, Too high of uranium mass in spent resin waste stream
4.2.9.10, 4.2.9.19, 4.2.9.21, 4.2.9.23, 4.2.10.10, 4.2.10.12, 4.3.9.10, 4.3.9.19, 4.3.9.21, 4.3.9.23, 4.3.10.10, and 4.3.10.12	Uranium is inadvertently carried over from the concentrator (1 or 2) to the condenser and subsequently, the condenser condensate collection tanks	Accidental criticality from fissile solution not confined in safe geometry	S.C.09, Carryover of uranium to the condenser or condensate tanks
4.2.9.36 and 4.3.9.36	Uranium solution is transferred via a leak between the process system and heater/cooling jackets or coils on a tank or in an exchanger	Accidental criticality from fissile solution not confined in safe geometry	S.C.07, Uranium-containing solution leaks to chilled water or steam condensate system
4.1.1.8, 4.1.1.22, 4.2.1.9, 4.2.1.17, 4.2.1.23, 4.2.9.11, 4.2.9.14, 4.2.9.17, 4.2.9.23, 4.2.9.30, 4.2.9.32, 4.2.10.14, 4.3.1.10, 4.3.1.18, 4.3.1.24, 4.3.9.11, 4.3.9.14, 4.3.9.17, 4.3.9.23, 4.3.9.30, 4.3.9.32, 4.3.10.14, 4.4.1.8, 4.4.1.22, 4.5.1.9, 4.5.1.22, and 4.5.2.8	Carryover of high-vapor content gases or entrance of solutions into the process ventilation header can cause poor performance of the retention bed materials and release radionuclides	High airborne radionuclide release, affecting workers and the public	S.R.04, Carryover of heavy vapor or solution into the process ventilation header causes downstream failure of retention bed, releasing radionuclides

PHA Summary – Uranium Recovery and Recycle (continued)

Adverse Event Summary for Uranium Recovery and Identification of Accident Sequences Needing Further Evaluation (4 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
4.1.1.10, 4.1.1.15, 4.1.1.23, 4.2.1.11, 4.2.1.15, 4.2.1.24, 4.2.2.1, 4.2.2.4, 4.2.3.11, 4.2.3.13, 4.2.3.18, 4.2.3.22, 4.2.3.23, 4.2.3.24, 4.2.4.10, 4.2.5.10, 4.2.6.11, 4.2.7.8, 4.2.8.11, 4.2.8.16, 4.2.8.23, 4.2.9.16, 4.2.9.28, 4.2.9.34, 4.3.1.12, 4.3.1.16, 4.3.1.25, 4.3.2.1, 4.3.2.4, 4.3.3.11, 4.3.3.13, 4.3.3.18, 4.3.3.22, 4.3.3.23, 4.3.3.24, 4.3.4.10, 4.3.5.10, 4.3.6.11, 4.3.7.8, 4.3.8.11, 4.3.8.16, 4.3.8.23, 4.3.9.16, 4.3.9.28, 4.3.9.34, 4.4.1.10, 4.4.1.15, 4.4.1.23, 4.5.1.11, 4.5.1.15, 4.5.1.23, 4.5.2.10, 4.5.2.15, 4.5.2.23, 4.5.3.8, 4.5.3.12, and 4.5.3.19	High-dose radionuclide solution is spilled from the system	Radiological release of high-dose solution with potential to impact workers, the public, or environment	S.R.01, Spill of product solution in hot cell area
4.2.1.12, 4.2.1.24, 4.2.2.1, 4.2.3.11, 4.2.3.13, 4.2.3.18, 4.2.3.22, 4.2.3.23, 4.2.4.10, 4.2.5.10, 4.2.6.11, 4.2.8.11, 4.2.8.16, 4.2.8.23, 4.2.9.16, 4.2.9.28, 4.2.9.34, 4.2.9.35, 4.3.1.12, 4.3.1.16, 4.3.1.12, 4.3.1.25, 4.3.2.1, 4.3.3.11, 4.3.3.13, 4.3.3.18, 4.3.3.22, 4.3.3.23, 4.3.4.10, 4.3.5.10, 4.3.6.11, 4.3.8.11, 4.3.8.16, 4.3.8.23, 4.3.9.16, 4.3.9.28, 4.3.9.34, 4.3.9.35, 4.4.1.10, 4.4.1.15, 4.4.1.23, 4.5.1.11, 4.5.1.23, 4.5.2.10, 4.5.2.15, 4.5.2.23, and 4.5.3.19	High-dose radionuclide solution is sprayed from the system, causing high airborne radioactivity	Radiological release of high-dose spray that remains suspended in the air, giving high dose to workers or the public	S.R.03, Spray of product solution in hot cell area
4.2.9.37, 4.2.9.36, 4.3.9.36, and 4.3.9.37	High-dose radionuclide solution leaks through an interface between the process system and a heating/cooling jacket coil into a secondary system (e.g., chilled water or steam condensate), releasing radionuclides to workers, the public, and environment	High-dose radionuclide solution that leaks to the environment through another system to expose workers or the public	S.R.13, High-dose, radionuclide-containing solution leaks to chilled water or steam condensate system

PHA Summary – Uranium Recovery and Recycle (continued)

Adverse Event Summary for Uranium Recovery and Identification of Accident Sequences Needing Further Evaluation (4 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
4.1.1.25, 4.2.1.26, 4.2.8.25, 4.3.1.27, 4.3.8.25, 4.4.1.25, 4.5.1.25, 4.5.2.25, and 4.5.3.21	Hydrogen buildup in tanks or system, leading to explosive concentrations	Explosion leading to radiological and criticality concerns	S.F.02, Accumulation of flammable gas in tanks or systems
4.1.1.24, 4.2.1.25, 4.2.8.24, 4.2.10.18, 4.3.1.26, 4.3.8.24, 4.3.10.18, 4.4.1.24, 4.5.1.24, 4.5.2.24, and 4.5.3.20	Higher dose than normal due to double-batching an activity or due to buildup of radionuclides in the system over time	Radiation dose is elevated over normal operational levels, but does not exceed low consequence values for exposure to workers due to shielding	Hot cell shielding is credited as the normal condition, mitigating safety feature for this hazard (adverse condition does not represent failure of the safety function of the IROFS)
4.2.4.8 and 4.3.4.8	High temperature pre-elution or regeneration reagent causes unknown impact on IX resin	Consequence is not fully understood	Tentatively S.R.14
4.2.10.6 and 4.3.10.6	Same as S.C.08 except with low-dose solution from condenser condensate	Low consequence resulting in contaminated system	N/A
4.2.10.8, 4.2.10.11, 4.2.10.17, 4.3.10.8, 4.3.10.11, and 4.3.10.17	Spill or spray of low-dose condensate	Low consequence resulting in contaminated surfaces and dose to worker below intermediate consequence dose levels	N/A

PHA Summary – Waste Handling

Adverse Event Summary for Waste Handling and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
5.1.1.13	High uranium content product solution is directed to the high-dose waste collection tanks by accident	Solution from this tank is solidified in a non-favorable geometry process with potential to result in accident nuclear criticality at the high uranium concentration	S.C.10, Fissile solution in high-dose waste collection tanks (a non-fissile solution boundary)
5.2.1.13 and 5.2.2.13	High uranium content product solution enters the low-dose waste collection tanks by accident	Solution from this tank is solidified in a non-favorable geometry process with potential to result in accidental nuclear criticality at the high uranium concentration	S.C.10, Fissile solution is directed to the low-dose waste collection tank
5.4.1.1	High uranium content accumulates in the TCE reclamation evaporator	The mass of uranium may exceed a safe mass and result in an accidental nuclear criticality without monitoring and controls	S.C.22, High concentration of uranium in the TCE evaporator residue
5.4.2.1	Dissolved uranium products may accumulate in the silicone oil waste stream	The mass of uranium may exceed a safe mass and result in an accidental nuclear criticality without monitoring and controls	S.C.23, High concentration in the spent silicone oil waste
5.1.1.24 and 5.1.4.23	Hydrogen buildup in tanks or system leads to explosive concentrations	Explosion leads to radiological and criticality concern	S.F.02, Accumulation of flammable gas in tanks or systems
5.1.1.4, 5.1.1.16, 5.1.4.4, 5.1.4.15, and 5.1.4.17	Several tank or components vented to the process vessel ventilation system overflow and send high-dose solution into process ventilation system components that exit the hot cell boundary	Radiological release may cause a high-dose exposure to workers and the public	S.R.04, High-dose solution from a tank or component overflows into the process ventilation system, compromising the retention beds
5.1.1.6 and 5.1.4.6	The purge air system (an auxiliary system that originates outside the hot cell boundary) allows high-dose radionuclides to exit the boundary in an uncontrolled manner	Radiological release may cause a high-dose exposure to workers and the public	S.R.16, High-dose solution backflows into the purge air system

PHA Summary – Waste Handling (continued)

Adverse Event Summary for Waste Handling and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
5.1.1.10, 5.1.1.14, 5.1.1.22, 5.1.2.26, 5.1.2.31, 5.1.4.10, 5.1.4.13, 5.1.4.21, 5.1.5.16, 5.1.5.19, 5.1.5.20, 5.3.1.14, 5.3.1.17, and 5.3.1.18	Spills from multiple sources; materials originating from high-dose process solutions are spilled from the system or process that normally confines them	Radiological release may cause a high-dose exposure to workers and the public	S.R.01, High-dose solution spill in the hot cell waste handling area
5.1.1.21, 5.1.2.28, and 5.1.4.20	Several tanks or components vented to the process vessel ventilation system evolve high liquid vapor concentrations, resulting in accelerated high-dose radionuclide release to the stack from wetted retention beds	Radiological release may cause a high-dose exposure to workers and the public	S.R.04, High-dose radionuclide release due to high vapor content in exhaust
5.1.1.22, 5.1.2.26, 5.1.2.31, 5.1.2.32, 5.1.4.10, and 5.1.4.21	Catastrophic failure of a component (high pressure or detonation) leads to rapid release of solution and higher airborne levels	Radiological release may cause a high-dose exposure to workers and the public	S.R.03, High-dose solution spray events from equipment upsets may cause high airborne radioactivity
5.1.2.9, 5.1.2.18, 5.1.2.19, and 5.1.2.21	Adverse events in the concentrator or evaporator systems lead to carryover of high-dose solution into the condenser, resulting in high-dose radionuclides in the low-dose waste collection tanks	Radiological exposure levels on the low-dose encapsulated waste may exceed intermediate or high consequence levels	S.R.17, Carryover of high-dose solution into condensate (a low-dose waste stream)
5.1.2.33	Normally low-dose vapor in the condenser leaks through the boundary into the chilled water system	Radiological release may cause a high-dose exposure to workers and the public	S.R.13, Process vapor from the evaporator leaks across the condenser cooling coils into the chilled water system

PHA Summary – Waste Handling (continued)

Adverse Event Summary for Waste Handling and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
5.1.5.8	High-dose solution is inadvertently misfed into the solidification hopper	Radiological release may cause a high-dose exposure to workers and the public	S.R.18, High-dose solution flows into the solidification hopper
5.5.1.1	Due to several potential initiators, the payload container or the shipping cask of high-dose encapsulated waste is dropped during transfer from the storage location to the conveyance	Radiological issue – Depending on damage from the drop, workers could receive high-dose radiation exposure. Unshielded package may impact dose rates at the controlled area boundary.	S.R.32, Container or cask dropped during transfer

PHA Summary – Target Receipt

Adverse Event Summary for Target Receipt and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
6.1.2.4, 6.1.2.8, 6.1.2.9, 6.1.2.11, 6.1.2.14, and 6.1.2.15	Handling damage to the target basket fixed-interaction passive design feature leads to accidental nuclear criticality	Accidental nuclear criticality leads to high dose to workers and potential dose to the public	S.C.21, Target basket passive design control failure on fixed interaction spacing
6.1.2.7, 6.1.2.10, 6.2.1.1, 6.2.1.5, 6.2.2.1, 6.2.2.2, 6.2.2.4, 6.2.2.5, 6.2.3.3, 6.2.4.1, 6.2.4.2, 6.2.4.4, 6.2.6.1, 6.2.6.3, and 6.2.6.4	Too much uranium mass is handled at once either through operator error or inattention to housekeeping	Accidental nuclear criticality leads to high dose to workers and potential dose to the public	S.C.02, Operator exceeds batch handling limits during target disassembly operations in the hot cell
6.2.1.6, 6.2.2.9, 6.2.3.4, and 6.2.6.6	Operator accumulates more targets or [Proprietary Information] containers into specific room than allowed and violates interaction control	Accidental nuclear criticality leads to high dose to workers and potential dose to the public	S.C.03, Failure of administrative control on interaction limit during handling of targets and irradiated [Proprietary Information]
6.2.1.3, 6.2.1.4, 6.2.1.5, 6.2.2.2, 6.2.2.4, 6.2.2.6, 6.2.3.1, 6.2.3.2, 6.2.3.3, 6.2.5.1, 6.2.5.3, 6.2.5.4, 6.2.5.8, 6.2.6.1, 6.2.6.2, 6.2.6.3, and 6.2.6.5	Too much uranium in the solid waste container (that is not safe-geometry) entering the solid waste encapsulation process (where moderator will be added in the form of water)	Accidental nuclear criticality leads to high dose to workers and potential dose to the public	S.C.17, [Proprietary Information] residual determination fails, and used target housings have too much uranium in solid waste encapsulation waste stream
6.1.1.5, and 6.1.1.9	Cask involved in an in-transit accident or improperly closed prior to shipment, leading to streaming radiation	High dose to workers during receipt inspection and opening activities	S.R.28, High dose to workers during shipment receipt inspection and cask preparation activities due to damaged irradiated target cask
6.1.1.10	Cask involved in in-transit accident or targets failed during irradiation, leading to excessive offgassing from damaged targets	High dose to workers during receipt inspection and opening activities	S.R.29, High dose to workers from release of gaseous radionuclides during cask receipt inspection and preparation for target basket removal

PHA Summary – Target Receipt (continued)

Adverse Event Summary for Target Receipt and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
6.1.1.11, 6.1.1.12, 6.1.2.1, 6.1.2.13, and 6.1.2.16	Seal between cask and hot cell docking port fails from a number of causes	High dose to workers from streaming radiation and/or high airborne radioactivity	S.R.30, Cask docking port failures lead to high dose to workers due to streaming radiation and/or high airborne radioactivity
6.1.1.1	Cask involved in a crane movement incident, leading to streaming radiation	High dose to workers during receipt inspection and opening activities	S.R.32, High dose to workers during shipment receipt inspection and cask preparation activities due to damaged cask in crane movement incident
6.1.2.3 and 6.1.2.5	Improper handling activities result in high external dose rates through the hot cell wall when removing the target basket and setting it in the target basket carousel shielded well	High external dose to workers	S.R.19, High target basket retrieval dose rate
6.1.2.10, 6.1.2.15, 6.2.1.5, 6.2.2.2, 6.2.2.4, 6.2.3.3, 6.2.4.2, 6.2.5.4, 6.2.6.1, and 6.2.6.3	[Proprietary Information] spilled or ejected in an uncontrolled manner during various target and container-handling activities or during target-cutting activities	High dose to workers or the public may result from uncontrolled accumulation of irradiated [Proprietary Information]	S.R.20, Radiological spill of irradiated targets in the hot cell area
6.1.2.15	Operations removing the target basket (potentially in a heavy shielding housing) with a hoist leads to striking the wall and damaging the hot cell wall shielding function	High dose to workers due to degraded shielding	S.R.21, Damage to the hot cell wall providing shielding
6.2.4.5	Delays in processing a batch of removed [Proprietary Information] results in long-term heating outside of target housing	High dose to workers from high airborne radioactivity	S.R.22, Decay heat buildup in unprocessed [Proprietary Information] removed from targets leads to higher high dose radionuclide offgassing

PHA Summary – Target Receipt (continued)

Adverse Event Summary for Target Receipt and Identification of Accident Sequences Needing Further Evaluation (3 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
6.2.4.6 and 6.2.4.7	Improper venting of the chamber or premature opening of the valve during processing of a previously added batch results in release of high-dose radionuclides to the hot cell space	High dose to workers from high airborne radioactivity	S.R.23, Offgassing from irradiated target dissolution tank occurs when the upper valve is opened
6.2.5.5, 6.2.5.6, and 6.2.5.7	The seal on the bagless transport door fails and leads to high dose radionuclides escaping the hot cell containment or confinement boundary	High dose to workers from high airborne radioactivity	S.R.24, Bagless transport door failure

PHA Summary – Ventilation

Adverse Event Summary for Ventilation System and Identification of Accident Sequences Needing Further Evaluation

PHA item numbers	Bounding accident description	Consequence	Accident sequence
7.1.1.7 and 7.1.1.8	Too much uranium accumulated on the HEPA filter allows an accidental criticality when left in the wrong configuration	Accidental nuclear criticality leads to high dose to workers and potential dose to the public	S.C.24, High uranium content on HEPA filters
7.1.1.2, 7.1.1.3, and 7.1.1.6	Hydrogen buildup in the ventilation system, due to insufficient flow to sweep it away, leads to fire in the HEPA filters or carbon beds	A detonation or deflagration event in the ventilation system rapidly releases retained high-dose radionuclides, causing high airborne radioactivity	S.F.06, Accumulation of flammable gas in ventilation system components
7.1.1.10 and 7.2.1.19	Ignition source causes fire in the carbon bed	Fire event in the ventilation system rapidly releases retained high-dose radionuclides, causing high airborne radioactivity	S.F.05, Fire in the carbon bed
7.1.1.11 and 7.2.1.20	Overloading of HEPA filter leads to failure and release of accumulated radionuclide particulate	High dose to workers from high airborne radioactivity	S.R.25, HEPA filter failure
7.1.1.12, 7.1.1.14, and 7.2.1.21	The accumulated high-dose (and low-dose) radionuclides retained in the carbon bed are released through a flow, heat, or chemical reaction from the media (or the media is released)	High dose to workers from high airborne radioactivity	S.R.04, Carbon bed radionuclide retention failure
7.2.1.4, 7.2.1.7, 7.2.1.8, 7.2.1.9, 7.2.1.13, 7.2.1.14, 7.2.1.17, and 7.2.1.22	Loss of the negative air balance between zones (a confinement feature that prevents migration of radionuclides from areas of high dose and high concentration to areas of low concentration)	High dose to workers from high airborne radioactivity	S.R.26, Failed negative air balance from zone to zone or failure to exhaust a radionuclide buildup in an area
7.2.1.12 and 7.2.1.17	During an extended power outage, some solution systems freeze and cause failure of the piping system, leading to radiological spills	High dose to workers from high airborne radioactivity	S.R.27, Extended outage of heat, leading to freezing, pipe failure, and release of radionuclides from liquid process systems

PHA Summary – Node 8.0

Adverse Event Summary for Node 8.0 and Identification of Accident Sequences Needing Further Evaluation (6 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
8.2.1.5	Large leak leads to localized low oxygen levels that adversely impact worker performance and may lead to death	Standard industrial hazard – Localized asphyxiant	Nitrogen storage or distribution system leak
8.5.1.1 and 8.5.1.5	Operator double-batches allotted amount of material (fresh U, scrap U, [Proprietary Information], target batch) into one location or container during handling	Accidental criticality issue – Too much fissile mass in one location may become critical	S.C.02, Failure of AC on mass (batch limit) during handling of fresh U, scrap U, [Proprietary Information], and targets
8.5.1.3 and 8.5.1.5	Operator handling various containers of uranium or batches of uranium components brings two containers or batches closer together than the approved interaction control distance	Accidental criticality issue – Too much uranium mass in one location	S.C.03, Failure of AC on interaction limit during handling of fresh U, scrap U, [Proprietary Information], and targets
8.6.1.7	A liquid spill of recycle uranium or target dissolution solution occurs within the hot cell boundary	Criticality issue – Fissile solution may collect in unsafe geometry	S.C.04, A liquid spill of fissile solution occurs
8.6.1.9	Process solutions backflow through chemical addition lines to locations outside the hot cell boundary	Criticality issue – Fissile solution may collect in unsafe geometry	S.C.08, Fissile process solutions backflow through chemical addition lines
8.6.1.13	Improper installation of HEPA filters (and prefilters) leads to transfer of fissile uranium particulate into downstream sections of the ventilation system with uncontrolled geometries	Accidental nuclear criticality leads to high dose to worker and potential dose to public	S.C.24, High uranium content on HEPA filters
8.5.1.2 and 8.5.1.5	Operator handling enriched solutions pours solution into an unapproved container	Criticality hazard – Too much uranium mass in one place can lead to accidental nuclear criticality	S.C.27, Failure of AC on volume limit during sampling
8.4.1.8 and 8.6.1.12	Drop of a hot cell cover block or other heavy object damages SSCs relied on for safety	Criticality issue – Structural damage could adversely damage SSCs relied on for safety, leading to accidents with intermediate or high consequence	S.C.28, Crane drop accident over hot cell or other area with SSCs relied on for safety

PHA Summary – Node 8.0 (continued)

Adverse Event Summary for Node 8.0 and Identification of Accident Sequences Needing Further Evaluation (6 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
8.1.2.7 and 8.1.2.12	A general facility fire (caused by vehicle accident inside or outside of the facility, wildfire, combustible fire in non-industrial areas, or fire in non-licensed material processing areas) spreads to areas in the building that contain licensed material	Uncontrolled fire can lead to damage to SSCs relied on for safety, resulting in chemical, radiological, or criticality hazards that represent intermediate to high consequence to workers, the public, and environment	S.F.08, General facility fire
8.2.1.7	Leak of hydrogen in the facility attains an explosive mixture and finds an ignition source, leading to detonation or deflagration of the mixture	May lead to an explosion (detonation or deflagration), depending on the location in the facility where the hydrogen leaks from. Explosion may compromise SSCs to various degrees and may lead to intermediate or high consequence events.	S.F.09, Hydrogen explosion in the facility due to a leak from the hydrogen storage or distribution system
8.6.1.11	Electrical fire sparks larger combustible fire in one of the hot cells	Radiological and criticality issue – Depending on the location and quantity of combustibles or flammables left in the area, a fire in the hot cell area could rupture systems with high-dose fission products and/or high uranium content, leading to spills and airborne releases	S.F.10, Combustible fire occurs in hot cell area
8.1.2.9 and 8.4.1.9	A natural gas leak develops in the steam generator room and finds an ignition source, resulting in a detonation or deflagration that damages SSCs	Potential explosion that could catastrophically damage nearby SSCs. Depending on the extent of the damage to SSCs, an accidental nuclear criticality or an intermediate or high consequence exposure to workers could occur.	S.F.11, Detonation or deflagration of natural gas leak in steam generator room
8.1.2.7, 8.3.1.2, and 8.6.1.5	Vehicle inside building strikes fresh uranium dissolution system component, leading to a spill or accidental criticality due to disruption of geometry and/or interaction	Accidental nuclear criticality leads to high dose to workers and potential dose to public	S.M.01, Vehicle strikes SSC relied on for safety and causes damage or leads to an accident sequence of intermediate or high consequence
8.4.1.6	TBD (impact must be evaluated after determining all IROFS that rely on personnel action)	TBD (impact must be evaluated after determining all IROFS that rely on personnel action)	S.M.02, Facility evacuation impacts on operation

PHA Summary – Node 8.0 (continued)

Adverse Event Summary for Node 8.0 and Identification of Accident Sequences Needing Further Evaluation (6 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
8.1.2.13	Flooding from external events and internal events compromises the safe geometry slab area under certain tanks. Depending on the liquid level, interspersed moderation of components may be impacted. Floor storage arrays are subject to stored containers floating (loss of interaction control).	Criticality issue – Water accumulation under safe geometry storage vessels or in safe interaction storage arrays, causing interspersed moderation. Flooding could compromise safe-geometry storage capacity for subsequent spills of fissile solution. Either event could compromise criticality safety.	S.M.03, Flooding occurs in building due to internal system leak or fire suppression system activation (likely)
8.1.1.1	Large tornado strikes the facility	Radiological, chemical, and criticality issue – Structural damage could adversely damage SSCs relied on for safety. Facility could lose all electrical distribution. Facility could lose chilled water system function (cooling tower outside of building).	S.N.01, Tornado impact on facility and SSCs
8.1.1.2	Straight-line winds strike the facility	Radiological, chemical, and criticality issue – Structural damage could adversely damage SSCs relied on for safety. Facility could lose all electrical distribution. Facility could lose chilled water system function (cooling tower outside of building).	S.N.02, High straight-line wind impact on facility and SSCs
8.1.1.3	A 48-hr probable maximum precipitation event strikes the facility	Radiological, chemical, and criticality issue – Structural damage from roof collapse could adversely damage SSCs relied on for safety	S.N.03, Heavy rain impact on facility and SSCs
8.1.1.4	Flooding occurs in the area in excess of 500-year return frequency	Radiological issue – Minor structural damage is not anticipated to impact SSCs relied on for safety except that the facility could lose all electrical distribution and/or chilled water system function (cooling tower outside of building)	S.N.04, Flooding impact on facility and SSCs

PHA Summary – Node 8.0 (continued)

Adverse Event Summary for Node 8.0 and Identification of Accident Sequences Needing Further Evaluation (6 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
8.1.1.6	Safe shutdown earthquake strikes – Seismic shaking can lead to damage of the facility and partial to complete collapse. This damage impacts SSCs inside and outside the hot cell boundary. Leaks of fissile solution, compromise of safe-geometry, and safe interaction storage in solid material storage arrays and pencil tanks or vessels containing enriched uranium solutions.	Radiological, chemical, and criticality issue – Structural damage could adversely damage SSCs relied on for safety. Facility could lose all electrical distribution. Facility could lose chilled water system function (cooling tower outside of building).	S.N.05, Seismic impact on facility and SSCs
8.1.1.9, 8.1.1.10	Heavy snowfall or ice buildup exceeds design loading of the roof, resulting in collapse of the roof and damage to SSCs (e.g., those outside of the hot cells)	Radiological, chemical, and criticality issue – Structural damage from roof collapse could adversely damage SSCs relied on for safety. Loss of site electrical power is highly likely in heavy ice storm event.	S.N.06, Heavy snowfall or ice buildup on facility and SSCs
8.6.1.8	Any stored high-dose product solution spills within the hot cell boundary	Radiological issue – High-dose solution is unconfined or uncontrolled and can cause exposures to workers, the public, and environment	S.R.01, A liquid spill of high-dose fission product solution occurs
8.5.1.5	Operator spills diluted sample outside of the hot cell area	Radiological issue – Potential spray or vaporization of radionuclide containing vapor-causing adverse worker exposure (based on typical low quantities handled in the laboratory, this is postulated to be an intermediate consequence event)	S.R.01, Spill of product solution in laboratory
8.6.1.10	Recycle uranium transferred out before lag storage decay complete or with significant high-dose radionuclide contaminants	Radiological issue – High radiation may occur in non-hot cell areas, impacting workers with higher than normal external doses	S.R.05, High-dose solution exits hot cell shielding boundary (destined for UN blending and storage tank)

PHA Summary – Node 8.0 (continued)

Adverse Event Summary for Node 8.0 and Identification of Accident Sequences Needing Further Evaluation (6 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
8.6.1.9	Process solutions backflow through chemical addition lines to locations outside the hot cell boundary	Radiological issue – High radiation may occur in non-hot cell areas, impacting workers with higher than normal external doses	S.R.16, High-dose process solutions backflow through chemical addition lines
8.6.1.2 and 8.6.1.3	An improperly sealed cover block or transport door (e.g., for cask transfers) offer large opening potentials for radiation streaming	Radiological issue – Depending on location of damage, some streaming of high radiation may occur, impacting workers with higher than normal external doses	S.R.21, Damage to the hot cell wall penetration, compromising shielding
8.6.1.1	The seal on the bagless transport door fails and leads to high-dose radionuclides escaping the hot cell confinement boundary	Radiological issue – Degraded or loss of cascading negative air pressure between zones may allow high radiological airborne contamination to release without proper filtration and adsorption, leading to higher than allowed exposure rates to workers and the public	S.R.24, Bagless transport door failure
8.6.1.13	Following process upsets and over long periods of operation, contamination levels in downstream components leads to high dose during maintenance and to uncontrolled accumulation of fissile material	Radiological and criticality issue – Following process upsets and over long periods of operation, contamination levels in downstream components can lead to high dose during maintenance and to uncontrolled accumulation of fissile material	S.R.25, HEPA filter failure
8.6.1.2, 8.6.1.3, and 8.6.1.6	An improperly sealed cover block or transport door (e.g., for cask transfers) compromises negative air pressure balance	Radiological issue – Degraded or loss of cascading negative air pressure between zones may allow high radiological airborne contamination to release without proper filtration and adsorption, leading to higher than allowed exposure rates to workers and the public	S.R.26, Failed negative air balance from zone to zone or failure to exhaust a radionuclide buildup in an area
8.5.1.7 and 8.5.1.8	Laboratory technician is burned by solutions containing radiological isotopes during sample analysis activities	Radiological issue – Burns may lead to intermediate consequence events if eyes are involved	S.R.31, Chemical burns from contaminated solutions during sample analysis

PHA Summary – Node 8.0 (continued)

Adverse Event Summary for Node 8.0 and Identification of Accident Sequences Needing Further Evaluation (6 pages)

PHA item numbers	Bounding accident description	Consequence	Accident sequence
8.4.1.8, 8.6.1.4, and 8.6.1.12	Drop of a hot cell cover block or other heavy object damages SSCs relied on for safety	Radiological and criticality issue – Structural damage could adversely damage SSCs relied on for safety, leading to accidents with intermediate or high consequence	S.R.32, Crane drop accident over hot cell or other area with SSCs relied on for safety
8.2.1.1	All nitric acid from a nitric acid storage tank is released in 1 hr from the chemical preparation and storage room	Standard industrial accident with potential to impact SSCs or cause additional accidents of concern	S.CS.01, Nitric acid fume release

Integrated Safety Analysis Questions?

U.S. Nuclear Regulatory Commission
ACRS Subcommittee Review

Chapter 13, Safety Analysis
August 23, 2017

General Safety Analysis Information

- Accident sequences evaluated using both qualitative and quantitative techniques
  - Most of quantitative consequence estimates are for releases to an uncontrolled area (public)
  - Worker safety consequence estimates are primarily qualitative
    - As facility final design matures, quantitative worker safety consequence analyses will be performed
- Accidents for operations with special nuclear matter (SNM) (including irradiated target processing, target material recycle, waste handling, and target fabrication), radiochemical, and hazardous chemicals were analyzed
- Initiating events for analyzed sequences include operator error, loss of power, external events, and critical equipment malfunctions or failures
- Shielded and unshielded criticality accidents assumed to have high consequences to worker if not prevented
- Updated frequency (likelihood) and worker and public quantitative safety consequences will be provided in Operating License Application

Accident Sequences Evaluated and Organization

Accident Sequences Evaluated

- Spill and Spray Accidents – Radiological and criticality (Section 13.2.2)
- Dissolver Offgas Accidents -- Radiological (Section 13.2.3)
- Leaks into Auxiliary Systems – Radiological and criticality (Section 13.2.4)
- Loss of Electrical Power Accidents (Section 13.2.5)
- Natural Phenomena Accidents (Section 13.2.6)
- Other Accidents (Section 13.2.7)

Accident Analysis Organization

- Initial conditions, including source term
- Event initiating conditions
- Description of accident sequences
- Function of components or barriers
- Unmitigated likelihood
- Radiation source term
- Evaluation of potential radiological consequences
- Identification of items relied on for safety (IROFS) and associated functions
- Mitigation estimates

Accident-Initiating Events

- Criticality accident
- Loss of electrical power
- External events (meteorological, seismic, fire, flood)
- Critical equipment malfunction
- Operator error
- Facility fire (explosion is included in this category)
- Any other event potentially related to unique facility operations

PHA Top-Level Accident Sequence Category	Definition
S.C.	Criticality
S.F.	Fire/Explosion
S.R.	Radiological
S.M.	Man-Made
S.N.	Natural Phenomena
S.CS.	Chemical Safety

Sprays and Spills Accident Initial Conditions

- Spray and spill events which could cause radiological exposure hazards and would represent a hazard to workers from direct exposure or inhalation and an inhalation exposure hazard to public in unmitigated scenario
- Fissile solution leak events which cause radiological and criticality hazards and would represent worker safety concerns
- Three solutions evaluated to bound range of process streams
  - Process tank containing low-dose uranium solutions, with no or trace fission products located in a contact maintenance-type of enclosure typical (e.g., target fabrication systems)
  - Process tank containing high-dose uranium solutions located in a hot cell-type of enclosure (e.g., irradiated target dissolution system)
  - Process tank containing ^{99}Mo product solution located in a hot cell-type of enclosure (e.g., Mo-99 purification system which does not lead to a criticality safety concern)
- Bounding radionuclide concentrations in liquid streams were developed for processes source term calculations (NWMI-2013-CALC-011)
  - Target dissolution, Mo recovery and purification, uranium recovery and recycle
  - Radionuclide concentrations are based on University of Missouri Research Reactor (MURR) target material balances

Sprays and Spill Initiating Event

- Process equipment failure, but also could be operator error or initiated by a fire/explosion
- Multiple mechanisms were identified during preliminary hazards analysis (PHA) that resulted in equivalent of a failure that spills or sprays tank contents, resulting in rapid and complete draining of a single tank to enclosure in vicinity of tank location

Liquid Sprays and Spills Accident Sequences

- Tank leak
  - Process vessel fail or personnel error causes tank contents to be emptied to vessel enclosure floor in vicinity of leaking tank
  - Tank liquid level monitoring and liquid level detection in enclosure floor sump region alarms, informing operators that a tank leak has occurred
  - Processing activities in affected system are suspended based on location of sump alarm
  - Operators identify leaking vessel locations and take actions to stop additions to leaking tank
  - Final stable condition is achieved when solution accumulated in sump has been transferred to a vessel available for particular sump material and removed from enclosure floor

Liquid Sprays and Spills Accident Sequences (continued)

- Spray leak (similar to tank leak)
  - Process line, containing pressurized liquid, ruptures or develops a leak during a transfer, spraying solution into source or receiver tank enclosure and transferring leaked material to an enclosure floor in vicinity of leak
  - Transfer liquid level monitoring and liquid level detection in enclosure floor sump region alarms, informing operators that a leak has occurred
  - Processing activities in affected system are suspended based on location of sump alarm
  - Operators identify location of leaking vessel and take actions to ensure that motive force of leaking transfer line has been deactivated
  - Final stable condition is achieved when solution accumulated in sump has been transferred to a vessel available for particular sump material and removed from enclosure floor
  - Maintenance activities to repair cause of a tank or spray leak are initiated after achieving final stable condition

Liquid Sprays and Spills Barriers

- Process vessel enclosure floor, walls, and ceiling provide a barrier that prevents transfer of radioactive material to an uncontrolled area
  - For accidents involving high-dose uranium solutions and ^{99}Mo product solution, process vessel enclosure floor, walls, and ceiling will provide shielding for worker
  - Enclosure structure barriers function throughout accident until (and after) a stable condition has been achieved
- Process enclosure secondary confinement (or ventilation) system provide a barrier to prevent transfer of radioactive material to an uncontrolled area during a liquid spill or spray accident from radioactive material in airborne particulate and aerosols generated by event
  - Secondary confinement system functions throughout accident until a stable condition has been achieved
- Process enclosure sump system represents a component credited (part of double-contingency analysis) for preventing occurrence of a solution-type accidental nuclear criticality due to spills or sprays of fissile material
  - Sump system functions throughout accident until a stable condition is achieved

Liquid Sprays and Spills Frequency

- Spray or spill initiated by operations or maintenance personnel error or equipment failures
  - Failure rates for tanks, vessels, pipes, and pumps estimated from WSRC-TR-93-262, *Savannah River Site Generic Data Base Development*
- Operator error and tank failure as initiating events estimated to have an unmitigated likelihood of "not unlikely"
- Liquid spill source terms dependent on vessel location in process system
- Source terms describe three configurations used to span range of initial conditions:
  - Low-dose uranium solutions bounded by maximum projected uranium concentration solution in target fabrication system
    - Primary attribute of low-dose uranium solutions used for consideration of direct exposure consequences is that fission products separated from recycled uranium to allow contact operation and maintenance of target fabrication system within ALARA guidelines
  - High-dose uranium solutions bounded by a spill from irradiated target dissolver after dissolution is complete
    - Target dissolution produces an aqueous solution containing uranyl nitrate, nitric acid, and fission products
  - ^{99}Mo product solution bounded by a small solution volume (less than 1 L) containing weekly inventory of product from processing MURR targets

Liquid Sprays and Spills Consequences

- Confinement release source terms are based on five-factor algebraic formula for calculating source terms for airborne release accidents from NUREG/CR 6410, *Nuclear Fuel Cycle Facility Accident Analysis Handbook*

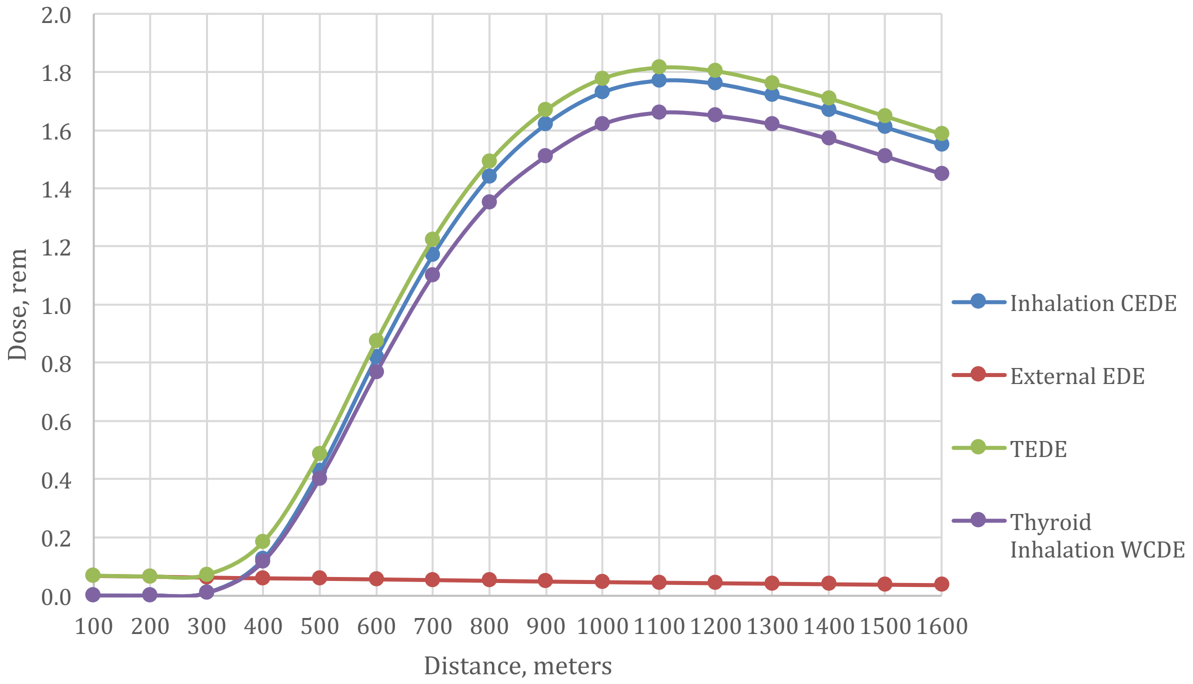
$$ST = MAR \times DR \times ARF \times RF \times LPF$$

ST = Source term (activity)
MAR = Material at risk (activity)
DR = Damage ratio (dimensionless)
ARF = Airborne release fraction (dimensionless)
RF = Respirable fraction (dimensionless)
LPF = Leak path factor (dimensionless)

- Mitigation of radioactive consequence required
- Prevention of criticality accident required

Liquid Sprays and Spills Results

- Consequence evaluation results for a 100 L (26.4-gal) spray release event
  - Unmitigated spray release of dissolver product solution is an immediate consequence event
  - Nearest permanent resident → 32 m (0.27 mi)
  - Dissolver product spray unmitigated dose estimate is 300 mrem
  - Maximum receptor location (1,100 m [0.68 mi]) has a total effective dose equivalent (TEDE) of 1.8 rem
- Mitigated consequences are an order of magnitude lower due to credited IROFS in Zone I exhaust system



Liquid Sprays and Spills IROFS

- Three IROFS identified to control liquid spill and spray accidents from process vessels
  - IROFS RS-01, "Hot Cell Liquid Confinement Boundary"
  - IROFS RS-03, "Hot Cell Secondary Confinement Boundary"
  - IROFS RS-04, "Hot Cell Shielding Boundary"
- Liquid spill and spray events involving solutions containing fissile material have potential for producing liquid nuclear criticalities that must be prevented → IROFS are identified to control nuclear criticality aspects
  - IROFS CS-07, "Pencil Tank and Vessel Spacing Control Using Fixed Interaction Spacing of Individual Tanks or Vessels"
  - IROFS CS-08, "Floor and Sump Geometry Control on Slab Depth, Sump Diameter or Depth for Floor Spill Containment Berms"
  - IROFS CS-09, "Double-Wall Piping"

Dissolver Offgas Accident Initial Conditions

- Target dissolver and associated offgas treatment train assumed to be operational and in service prior to occurrence of any accident sequence that affects iodine removal units (IRU)
  - IRUs are assumed to be loaded with conservative bounding holdup inventory of iodine (NWMI-2013-CALC-011)
- No credible event has been identified where total captured inventory on IRUs would be released
  - Release of iodine generated from a single dissolution of four MURR targets at 8 hr after end of irradiation (EOI)
  - Maximum amount of iodine in four MURR target batch at 8 hr EOI
- Mass balance projects ~20 percent of iodine stays in dissolver solution and ~50 percent of elemental iodine (I_2) that does volatize will be captured in NO_x scrubbers (primary caustic scrubber) and transferred to high dose liquid waste system
  - For this analysis, all iodine assumed to evolve and remain in offgas stream going to IRUs

Dissolver Offgas Accident Initiating Events

- Three accidents (events) identified that have potential to impact normal efficient operation of target dissolver offgas treatment train including:
  - Excessive moisture carryover in gas stream due to a process upset in NO_x units
  - High gas flow rates due to process conditions in dissolver (e.g., excessive sweep air) or poor NO_x recovery
  - Loss of temperature control (loss of power or failure of temperature controller) to IRU
- These accidents have potential to reduce IRU efficiency
  - Reduced efficiency of dissolver offgas iodine removal unit (IRU) due to process upset or equipment failure

Dissolver Offgas Accident Sequences

- Accident sequences for loss of IRU efficiency include:
  - Target material being dissolved
  - Process upset occurs reduces IRU efficiency by an unspecified amount
  - Event identified by operator either from a process control alarm (e.g., low heater temperature) or a radiation alarm on gas stream or piping exiting hot cell
  - Following procedure, operator turns steam off to dissolver (to slow down dissolution process)
  - Operator troubleshoots upset condition and switches to back IRU, if warranted, and/or manually opens valve to pressure-relief tank in dissolver offgas system to capture offgas stream
- If initiator for event is loss of power or event creates a condition where vacuum in dissolver offgas system is lost, pressure-relief tank valve would automatically open to capture offgas stream
  - Tank sized to contain complete gas volume of a dissolution cycle

Dissolver Offgas Barriers

- IRUs primary iodine capture devices → Offgas system will have iodine guard beds downstream of each of primary noble gas adsorbers
- Process vessel ventilation (PVV) system piping will direct dissolver offgas to pressure-relief tank or through guard beds and into primary PVV system
- Dissolver offgas system will have iodine removal beds located downstream of point where target dissolver offgas treatment train discharges into PVV system
  - Provide redundant iodine removal capacity that backs up target dissolver offgas treatment train IRUs
- PVV discharges to Zone I exhaust header, which has a high-efficiency gas adsorption (HEGA) module that is a defense-in-depth component for accident sequence

Dissolver Offgas Frequency

- Loss of iodine removal efficiency initiated by operations or maintenance personnel error or equipment failures
- Failure rates for tanks, vessels, pipes, and pumps estimated from WSRC-TR-93-262
- Operator error and equipment failure as initiating events estimated to have an unmitigated likelihood of “not unlikely”
- Iodine source term is focus of accident sequence evaluation
  - No credit is taken for any iodine removal in dissolver scrubbers or residual iodine remaining in dissolver solution
  - Conversely, in this accident, previous capture iodine is not part of source term → Therefore, source term is 27,100 Ci
- Bounding iodine value includes 1.32 safety factor used in NWMI-2013-CALC-011
- Source term based on set of initial conditions designed to bound credible offgas scenarios:
  - All iodine in targets released into off gas system → No iodine or noble gases captured in NOx scrubbers or retained in dissolver solution
  - Iodine removal efficiency of dissolver offgas IRU goes to zero
  - Greater than expected release of material (e.g., no plating out of iodine, or subsequent iodine capture in downstream of unit operations)

Dissolver Offgas Consequences/Results

- Entire inventory released over a 2-hr period directly to 22.9 m (75-ft) stack and into environment
- Mitigation of radioactive consequence required

Target Dissolver Offgas Accident Total Effective Dose Equivalent

Distance (m)	TEDE (rem) Total
100	2.05E-01
200	1.98E-01
300	2.21E-01
400	6.41E-01
500	1.76E+00
600	3.18E+00
700	4.50E+00
800	5.47E+00
1,000	6.50E+00
1,100	***6.65E+00***
1,200	6.62E+00
1,300	6.50E+00
1,400	6.29E+00
1,500	6.06E+00
1,600	5.82E+00
1,700	2.05E-01

Dissolver Offgas IROFS

- IROFS RS-03, Hot Cell Secondary Confinement Boundary
  - As an active engineered control (AEC), this IROFS mitigates target dissolver offgas treatment train IRU failures is process vessel vent iodine removal beds
  - Iodine beds are located downstream of where target dissolver offgas treatment train discharges into PVV system → Beds provide a backup to target dissolver offgas treatment train IRUs
- IROFS RS-09, Primary Offgas Relief System
  - As an AEC, a relief device will be provided that relieves pressure from system to an on-service receiver tank maintained at vacuum, with capacity to hold gases generated by dissolution of one batch of targets in target dissolution tank
  - Safety function of this system prevents failure of primary confinement system by capturing gaseous effluents in a vacuum receiver
  - To perform this function, a relief device relieves into a vacuum receiver that is sized and maintained at a vacuum consistent with containing capacity of one target dissolution batch

Dissolver Offgas IROFS (continued)

- Defense-in-depth features:
  - Releases at stack will be monitored for radionuclide emissions to ensure overall removal efficiency of dissolver offgas system is reducing emissions to design levels and below regulatory limits
  - Spare dissolver offgas IRU available if online IRU unit loses efficiency
  - Primary carbon retention bed includes an iodine adsorption stage that reduces iodine as a normal backup to IRU

Leaks into Auxiliary Services and Systems Initial Conditions

- Accidents bound family of accidents where highly radioactive or fissile solution leaves hot cell or other shielded areas via auxiliary systems and creates a worker safety or criticality concern
- Initial conditions described as a tank or vessel (with a heating or cooling jacket) filled with process solution
  - Multiple vessels are projected to be at this initial condition throughout process
- Second primary configuration of concern is hot cell and target fabrication condensers associated with our concentrator or evaporator systems
  - Evaporator(s) initial conditions are normal operations, in which boiling solutions generate an overhead stream that needs to be condensed
- PHA identified fissile solution leaks into secondary containment as an event that could lead to an accidental nuclear criticality

Leaks into Auxiliary Services and Systems Initial Conditions (continued)

- Bounding source term expected to be dissolvers or feed tanks in Mo recovery and purification system during processing of MURR targets
  - Source terms associated with leaks and backflows into auxiliary system are dependent on vessel location in process system
  - High-dose uranium solution source term bounds this analysis
  - Solution leaks into cooling or heating system were bounded by irradiated target dissolver after dissolution is complete
- In unmitigated scenario, liquid solution leaks into secondary containment (e.g., cooling water jackets) represent a hazard to workers from direct radiological exposure or inhalation and an inhalation exposure hazard to public

Leaks into Auxiliary Services and Systems Initiating Events

- Initiating event described as a process equipment failure
  - PHA identified similar accident sequences in four nodes associated with leaks of enriched uranium solution into heating and/or cooling coils surrounding safe-geometry tanks or vessels
  - PHA identified predominately corrosive degradation of tank or overpressure of tank as potential causes that might damage this interface and allow enriched uranium solution to leak into cooling system media or into steam condensate for heating system
- Primary containment fails, which allows radioactive or fissile solutions to enter an auxiliary system
  - Radioactive or fissile solution leaks across mechanical boundary between a process vessel and associated heating/cooling jacket into heating/cooling media
  - Where heating/cooling jackets or heat exchangers are used to heat or cool a fissile and/or high-dose process solution → Potential exists for barrier between two to fail and allow fissile and/or high-dose process solution to enter auxiliary system
  - If auxiliary system is not designed with a safe-geometry configuration, or if system exits hot cell containment, confinement, or shielding boundary in an uncontrolled manner → Either an accidental criticality is possible or a high-dose to workers or public can occur

Leaks into Auxiliary Services and Systems Initiating Events (continued)

- Where auxiliary services enter process solution tanks → Potential exists for backflow of high-dose radiological and/or fissile process solution into auxiliary service systems (e.g., purge air, chemical addition line, water addition line)
- Since systems are not designed for process solutions → Event can lead to either accidental nuclear criticality or to high-dose radioactive exposures to workers occupying areas outside hot cell confinement boundary

Leaks into Auxiliary Services and Systems Accident Sequences

- PHA made no assumption about geometry or extent of heating/cooling subsystem
  - Consequently, credible accidental nuclear criticality could occur (no additional controls)
    1. Fissile solution enters into heating/cooling system not designed for fissile solution
    2. Solution exits shielded area and creates a high worker dose consequence
  - If system is not a closed loop, a direct release to atmosphere can also occur
- Accident sequence for a tank leak into cooling water (or heating) system includes:
  - Process vessel wall fails and tank contents leak into cooling jacket and medium, or process medium leaks into vessel
  - Tank liquid level monitoring and liquid level instrumentation are functional; however, depending on size of leak, tank level instrumentation may or may not detect that a tank has leaked
  - Cooling water system monitor (conductivity or pH) detects a change in cooling water and an alarm notifies operator
  - Operator places system in a safe configuration and troubleshoots source of leak
  - Maintenance activities to identify, repair, or replace cause of leak are initiated after achieving final stable condition
- Additional PHA accident sequences include backflow (siphon) or backup of process solutions into chemical or water addition systems

Leaks into Auxiliary Services and Systems Barriers

- Requires failure of primary confinement in a safe-geometry vessel or tank → Normal condition criticality safety control for process
- Same barrier provides primary containment of high-dose process solution to maintain solution within hot cell containment, confinement, and shielding boundary
- Heating and cooling systems have secondary loops (closed loops) → Thus, second failure is required for fissile solution to enter into a non-geometric-safe auxiliary system or into a non-shielded auxiliary system out of hot cells

Leaks into Auxiliary Services and Systems Frequency

- Leaks into auxiliary services can be initiated by mechanical failure of equipment boundaries between process solutions and auxiliary system fluids, or backflow of high-dose radiological or fissile solution to a chemical supply system
  - Failure rates for tanks, vessels, pipes, and pumps are estimated from WSRC-TR-93-262
- Failures resulting in leaks or backflows as initiating events are estimated to have an unmitigated likelihood of “not unlikely”

Leaks into Auxiliary Services and Systems Consequences

- Potential radiological exposure hazard of liquid spills bound consequences from radiation exposure for these accident sequences
- Even low-dose uranium solutions, while generally contact-handled, have similar exposure consequences due to criticality hazard
- Auxiliary systems located within hot cells requires shielding to control worker radiation exposure independent of whether process solution is contained in vessel or leaked into auxiliary system → A worker can receive a significant intermediate or high consequence dose rate in a short time
- Based on analysis of several accidental nuclear criticalities in industry identifies that a uranium solution criticality can yield between 1016 to 1017 fissions
  - Dose rates for anyone in target fabrication area can have high consequences
- Mitigation of radioactive consequence required
- Prevention of criticality accident required

Leaks into Auxiliary Services and Systems IROFS

- Hot cell shielding provides protection from leaks into heating and cooling closed loop auxiliary systems that result in redistribution of high-dose uranium solutions in hot cell
  - From a direct exposure perspective, this type of accident does not represent a failure or adverse challenge to hot cell shielding boundary function
- IROFS RS-04, Hot Cell Shielding Boundary
  - IROFS RS-04 functions prevents worker dose rates from exceeding exposure criteria due to presence of radioactive materials in hot cell vessels before or after a leak to cooling and heating auxiliary systems
  - Hot cell shielding boundary provides shielding for workers and public during normal operations to reduce worker exposure to an average of 0.5 mrem/hr
- IROFS CS-06, Pencil Tank and Vessel Spacing Control using the Diameter of the Tanks, Vessels, or Piping
  - All tanks, vessels, or piping systems involved in a process upset will be controlled with a safe-geometry confinement IROFS that consists of IROFS CS-06 to provide a diameter of vessels confinement or IROFS CS-26 to provide safe volume confinement

Leaks into Auxiliary Services and Systems IROFS (continued)

- IROFS CS-10, Closed Safe Geometry Heating or Cooling Loop with Monitoring and Alarm
  - As a passive engineered control (PEC), closed-loop safe-geometry heating or cooling loop with monitoring for uranium process solution or high-dose process solution will be provided to safely contain fissile process solution that leaks across this boundary, if primary boundary fails
  - Dual-purpose safety function of this closed loop prevents fissile process solution from causing accidental nuclear criticality and to prevent high-dose process solution from exiting hot cell containment, confinement, or shielded boundary causing excessive dose to workers and public, and/or release to environment
- IROFS CS-27, Closed Heating or Cooling Loop with Monitoring and Alarm
  - As a PEC, on evaporator or concentrator condensers, a closed cooling loop with monitoring for breakthrough of process solution will be provided to contain process solution that leaks across this boundary, if boundary fails
  - Applied to those high-heat capacity cooling jackets (requiring very large loop heat exchangers) servicing condensers where leakage is always from cooling loop to condenser, reducing back-leakage, and risk of product solutions entering condenser is very low by evaporator or concentrator design

Leaks into Auxiliary Services and Systems IROFS (continued)

- IROFS CS-20, Evaporator or Concentrator Condensate Monitoring
  - As an AEC, condensate tanks uses a continuously active uranium detection system to detect high carryover of uranium that shuts down evaporator feeding tank
  - Purpose of system
    - Detect anomalies in evaporator or concentrator indicating high uranium content in condenser (due to flooding or excessive foaming)
    - Prevent high concentration uranium solution from being available in condensate tank for discharge to a non-favorable geometry system or in condenser for leaking to non-safe geometry cooling loop
  - Safety function of IROFS is to prevent an accidental nuclear criticality
    - Detection system works by continuously monitoring condensate uranium content and detecting high uranium concentration and then shutting down evaporator to isolate condensate from condenser and condensate tank
    - Limiting setpoint, uranium monitor-detecting device closes an isolation valve in inlet to evaporator (or otherwise secure evaporator) to stop discharge of high-uranium content solution into condenser and condensate collection tank
    - Uranium monitor designed to produce a valve-open permissive signal that fails to an open state, closing valve on loss of electrical power

Leaks into Auxiliary Services and Systems IROFS (continued)

- IROFS CS-18, Backflow Prevention Device
  - As a PEC or AEC, chemical and gas addition ports to fissile process solution systems will enter through a backflow prevention device
    - Device may be an anti-siphon break, an overloop seal, or other active engineering feature that addresses conditions of backflow and prevents fissile solution from entering non-safe geometry systems or high-dose solutions from exiting hot cell shielding boundary in an uncontrolled manner
  - Backflow prevention device features for high-dose product solutions will be located inside hot cell shielding and confinement boundaries of IROFS RS-04 and RS-01, respectively
    - Feature is designed such that spills from overflow are directed to a safe geometry confinement berm controlled by IROFS CS-08
- IROFS CS-19, Safe Geometry Day Tanks
  - As a PEC, safe-geometry day tanks will be provided where first barrier cannot be a backflow prevention device
    - Safety function is to prevent accidental nuclear criticality by providing a safe-geometry tank if a fissile solution backs-up into an auxiliary chemical addition system.
    - Will be used where conventional backflow prevention in pressurized systems is not reliable
    - Safe-geometry day tank will be provided for those chemical addition activities where reagent cannot be added via an anti-siphon break since tank or vessel is not vented and operates under some backpressure conditions
  - Safe-geometry day tanks servicing high-dose product solutions systems will be located in hot cell shielding or confinement boundaries of IROFS RS-04 and RS-01, respectively

Leaks into Auxiliary Services and Systems IROFS (continued)

- Defense-in-depth features
  - All tanks will be vented and unpressurized under normal use
  - Heating and cooling systems will operate at pressures that are higher than processing systems that they heat or cool → Majority of system leakage would typically be in direction of heat transfer media to processing system.
  - All vented tanks are designed with level indicators that are available to operator to detect level of solution in a tank remotely
    - Operating procedures will identify an operational high-level fill operating limit for each tank
    - As part of level detector, a high-level audible alarm and light will be provided to indicate a high level above this operating limit so that operators can take action to correct conditions leading to failure of operating limit
    - With batch-type operation with typically low volume transfers, sizing of tanks will include sufficient overcapacity to handle reasonable perturbations in operations caused by variations in chemical concentrations and operator errors (adding too much).
  - Tank and vessel walls will be made of corrosion-resistant materials and have wall thicknesses that are rated for long service with harsh acid or basic chemicals
  - Purge and gas reagent addition lines (air, nitrogen, and oxygen) will be equipped with check valves to prevent flow of process solutions back into uncontrolled geometry portions (tanks, receivers, dryers, etc.) of delivery system

Loss of Power

- Multiple initiating events were identified by PHA that could result in loss of normal electric power
- Electrical power to RPF is lost due to an initiating event
- Uninterruptible power supply automatically provides power to systems that support safety functions, protecting RPF personnel and public
- Following systems are supported with an uninterruptible power supply:
  - Process and facility monitoring and control systems
  - Facility communication and security systems
  - Emergency lighting
  - Fire alarms
  - Criticality accident alarm systems
  - Radiation protection systems

Loss of Power Sequence

- On loss of power the following actions occur:
  - Inlet bubble-tight isolation dampers within Zone I ventilation system close and HVAC system is automatically placed into passive ventilation mode of operation
  - Process vessel vent system is automatically placed into passive ventilation mode of operation and all electrical heaters cease operation as part of passive operation mode
  - Pressure-relief confinement system for target dissolver offgas system is activated on reaching system relief set point, and dissolver offgas is confined in offgas piping, vessels, and pressure-relief tank (IROFS RS-09)
  - Process vessel emergency purge system is activated for hydrogen concentration control in tank vapor spaces (IROFS FS-03)
  - Uranium concentrator condensate transfer line valves are automatically configured to return condensate to feed tank due to residual heating or cooling potential for transfer of process fluids to waste tanks (IROFS CS-14/CS-15)
  - All equipment providing a motive force for process activities cease include:
    - Pumps performing liquid transfers of process solutions
    - Pumps supporting operation of steam and cooling utility heat transfer fluids
    - Equipment supporting physical transfer of items (primarily cranes)
- Operators follow alarm response procedures
- RPF is now in a stable condition

Loss of Power Barriers & Frequency

- All facility structural components of hot cell secondary confinement boundary (in a passive ventilation mode) and hot cell shielding boundary (walls, floors, and ceilings) will remain intact and functional
  - ESFs requiring power will activate or go to their fail-safe configuration
- Loss of power can be initiated by off-site events or mechanical failures of equipment
  - Failures resulting in loss of power as initiating events are estimated to have an unmitigated likelihood of “not unlikely”
- No additional IROFS have been identified specific to this event other than maintain operability of facility IROFS
  - Loss of normal electric power will not result in unsafe conditions for either workers or public in uncontrolled areas
- Standby diesel generator is a defense-in-depth feature to minimizing impact of a loss of power event

Loss of Power IROFS

- No additional IROFS have been identified specific to this event other than maintain operability of identified RPF IROFS
- Loss of normal electric power will not result in unsafe conditions for either workers or public in uncontrolled areas
- Defensive-in-depth
  - Standby diesel generator will be available for RPF operations

Natural Phenomena Events

- Tornado impact on RPF and structures, systems, and components (SSC)
  - Tornado impact on facility structure and fenestrations
  - Tornado impact on SSCs important to safety located outside primary facility
  - Impact to IROFs if building envelope is breached
  - Finite element model used for wind load analysis
- High straight-line winds impact RPF and SSCs
  - Impact on facility structure and fenestrations
  - Impact on SSCs important to safety located outside primary facility
  - Impact to IROFs if building envelope is breached
  - Finite element model used for wind load analysis
- Heavy rain impact on RPF and SSCs
  - Roof capacity for build-up of load from extreme rain
  - Impact on SSCs important to safety located outside primary facility
  - Lightning strike on RPF and provisions for electrical grounding

Natural Phenomena Events

- Flooding impact to RPF and SSCs
  - Site above 100- and 500-year floodplains
  - Building entry points examined for extreme run-off from higher ground north of site
  - Roof capacity for build-up of load from extreme rain
  - Flooding from rupture of internal and nearby external piping
- Seismic impact to RPF and SSCs
  - GMRS per Regulatory Guide 1.60 anchored to a 0.20 g PGA
  - Finite element model developed
  - Soil structure interaction analysis
  - Structural damping will follow recommendations of Regulatory Guide 1.61 ranging from 3 to 7 percent
- Heavy snow fall or ice buildup on RPF and SSCs
  - Roof capacity for build-up of load from snow or ice
  - Impact on SSCs important to safety located outside primary facility

Other Accidents Analyzed

75 Additional Accident Sequences Identified For Further Evaluation

Analyzed Accidents Sequences (6 pages)

PHA acc seq #	Descriptor	Preliminary IROFS Identified
S.R.01	High-dose solution or enriched uranium solution spill causing a radiological exposure hazard	• IROFS RS-01, Hot Cell Liquid Confinement Boundary • IROFS RS-03, Hot Cell Secondary Confinement Boundary • IROFS RS-04, Hot Cell Shielding Boundary • IROFS CS-07, Pencil Tank and Vessel Spacing Control using Fixed Interaction Spacing of Individual Tanks or Vessels • IROFS CS-08, Floor and Sum Geometry Control on Slab Depth, Sump Diameter or Depth for Floor Spill Containment Berms • IROFS CS-09, Double-Wall Piping • See Section 13.2.2.8
S.R.02	Spray release of solutions spilled from primary offgas treatment solutions, resulting in radiological consequences	• Bounded by S.R.01
S.R.03	Spray release of high-dose or enriched uranium-containing product solution, resulting in radiological consequences	• Bounded by S.R.01
S.R.04	Liquid enters process vessel ventilation system damaging IRU or retention beds, releasing retained radionuclides	• IROFS RS-09, Primary Offgas Relief System • IROFS RS-03, Hot Cell Secondary Confinement Boundary • See Section 13.2.3.8
S.R.05	High-dose solution enters the UN blending and storage tank	• Not credible or low consequence
S.R.06	High flow through IRU causing premature release of high-dose iodine gas	• Bounded by S.R.04
S.R.07	Loss of temperature control on the IRU leading to release of high-dose iodine	• Bounded by S.R.04
S.R.08	Loss of vacuum pumps	• Bounded by S.R.04
S.R.09	Loss of IRU or carbon bed media to downstream part of the system	• Bounded by S.R.04
S.R.10	Wrong retention media added to bed or saturated retention media	• Event unlikely with intermediate consequence
S.R.12	Mo product cask removed from the hot cell boundary with improper shield plug installation	• Event unlikely with intermediate consequence
S.R.13	High-dose containing solution leaks to chilled water or steam condensate system	• IROFS RS-04, Hot Cell Shielding Boundary • IROFS CS-06, Pencil Tank and Vessel Spacing Control using the Diameter of the Tanks, Vessels, or Piping • IROFS CS-10, Closed Safe-Geometry Heating or Cooling Loop with Monitoring and Alarm • IROFS CS-27, Closed Heating or Cooling Loop with Monitoring and Alarm • IROFS CS-20, Evaporator or Concentrator Condensate Monitoring • IROFS CS-18, Backflow Prevention Device • IROFS CS-19, Safe-Geometry Day Tanks • See Section 13.2.4.8

Other Accidents Analyzed (continued)

Analyzed Accidents Sequences (6 pages)

PHA acc seq #	Descriptor	Preliminary IROFS Identified
S.R.14	IX resin failure due to wrong reagent or high temperature	• Bounded by S.R.01
S.R.16	Backflow of high-dose radiological and/or fissile solution into auxiliary system (purge air, chemical addition line, water addition line, etc.)	• Bounded by S.R.13
S.R.17	Carryover of high-dose solution into condensate (a low-dose waste stream)	• IROFS RS-08, Sample and Analysis of Low Dose Waste Tank Dose Rate Prior to Transfer Outside the Hot Cell Shielded Boundary • IROFS RS-10, Active Radiation Monitoring and Isolation of Low-Dose Waste Transfer • See Section 13.2.7.1
S.R.18	High-dose solution flows into the solidification media hopper	• Low consequence event that does not challenge IROFS RS-04
S.R.19	High target basket retrieval dose rate	• Design evolved after PHA, accident sequence eliminated
S.R.20	Radiological spill of irradiated LEU target material in the hot cell area	• Bounded by S.R.01
S.R.21	Damage to the hot cell wall providing shielding	• Low consequence event that does not damage shielding function of IROFS RS-04
S.R.22	Decay heat buildup in unprocessed LEU target material removed from targets leads to higher-dose radionuclide offgasing	• Low consequence event
S.R.23	Offgasing from irradiated target dissolution tank occurs when the upper valve is opened	• IROFS RS-03, Hot Cell Secondary Confinement Boundary • See Section 13.2.2.8
S.R.24	Bagless transport door failure	• IROFS RS-03, Hot Cell Secondary Confinement Boundary • IROFS RS-04, Hot Cell Shielding Boundary • See Section 13.2.2.8
S.R.25	HEPA filter failure	• IROFS RS-03, Hot Cell Secondary Confinement Boundary • See Section 13.2.2.8
S.R.26	Failed negative air balance from zone-to-zone or failure to exhaust a radionuclide buildup in an area	• IROFS RS-03, Hot Cell Secondary Confinement Boundary • See Section 13.2.2.8
S.R.27	Extended outage of heat leading to freezing, pipe failure, and release of radionuclides from liquid process systems	• Highly unlikely event for process solutions containing fission products • Bounded by S.C.04 for target fabrication systems
S.R.28	Target or waste shipping cask or container not loaded or secured according to procedure, leading to personnel exposure	• Information will be provided in the Operating License Application
S.R.29	High dose to worker from release of gaseous radionuclides during cask receipt inspection and preparation for target basket removal	• IROFS RS-12, Cask Containment Sampling Prior to Closure Lid Removal • IROFS RS-13, Cask Local Ventilation During Closure Lid Removal and Docking Preparations • See Section 13.2.7.1
S.R.30	Cask docking port failures lead to high-dose to worker due to streaming radiation and/or high airborne radioactivity	• IROFS RS-04, Hot Cell Shielding Boundary • IROFS RS-15, Cask Docking Port Enabling Sensor • See Sections 13.2.2.8 and 13.2.7.1

Other Accidents Analyzed (continued)

Analyzed Accidents Sequences (6 pages)

PHA acc seq #	Descriptor	Preliminary IROFS Identified
S.R.31	Chemical burns from contaminated solutions during sample analysis	• Judged unlikely event with intermediate consequence
S.R.32	Crane load drop accidents	• IROFS FS-01, Enhanced Lift Procedure • IROFS FS-02, Overhead Cranes • See Section 13.2.7.1
S.C.01	Failure of facility enrichment limit	• Judged highly unlikely based on supplier's checks and balances
S.C.02	Failure of administrative control on mass (batch limit) during handling of fresh U, scrap U, LEU target material, targets, and samples	• IROFS CS-02, Mass and Batch Handling Limits for Uranium Metal, Uranium Oxides, Targets, and Laboratory Sample Outside Process Systems • IROFS CS-03, Interaction Control Spacing Provided by Administrative Control • IROFS CS-04, Interaction Control Spacing Provided by Passively Designed Fixtures and Workstation Placement • See Section 13.2.7.2
S.C.03	Failure of interaction limit during handling of fresh U, scrap U, LEU target material, targets, containers, and samples	• IROFS CS-02, Mass and Batch Handling Limits for Uranium Metal, Uranium Oxides, Targets, and Laboratory Sample Outside Process Systems • IROFS CS-03, Interaction Control Spacing Provided by Administrative Control • IROFS CS-04, Interaction Control Spacing Provided by Passively Designed Fixtures and Workstation Placement • See Section 13.2.7.2
S.C.04	Spill of process solution from a tank or process vessel leading to accidental criticality	• IROFS CS-06, Pencil Tank, Vessel, or Piping Safe Geometry Confinement using the Diameter of Tanks, Vessels, or Piping • IROFS CS-07, Pencil Tank and Vessel Spacing Control using Fixed Interaction Spacing of Individual Tanks or Vessels • IROFS CS-08, Floor and Sump Geometry Control of Slab Depth, Sump Diameter or Depth for Floor Spill Containment Berms • IROFS CS-09, Double-Wall Piping • IROFS CS-26, Processing Component Safe Volume Confinement • See Section 13.2.7.2
S.C.05	Leak of fissile solution into the heating or cooling jacket on the tank or vessel	• Bounded by S.R.13
S.C.06	System overflow to process ventilation involving fissile material	• IROFS CS-11, Simple Overflow to Normally Empty Safe Geometry Tank with Level Alarm • IROFS CS-12, Condensing Pot or Seal Pot in Ventilation Vent Line • IROFS CS-13, Simple Overflow to Normally Empty Safe Geometry Floor with Level Alarm in the Hot Cell Containment Boundary • See Section 13.2.7.2
S.C.07	Fissile solution leaks across mechanical boundary between process vessels and heating/cooling jackets into heating/cooling media	• Bounded by S.R.13
S.C.08	Backflow of high-dose radiological and/or fissile solution into auxiliary system (purge air, chemical addition line, water addition line, etc.)	• Bounded by S.R.13
S.C.09	High concentrations of uranium enter the concentrator or evaporator condensates	• IROFS CS-06, Pencil Tank, Vessel, or Piping Safe Geometry Confinement using the Diameter of Tanks, Vessels, or Piping • IROFS CS-07, Pencil Tank and Vessel Spacing Control Using Fixed Interaction Spacing of Individual Tanks or Vessels • IROFS CS-26, Processing Component Safe Volume Confinement • See Section 13.2.7.2

Other Accidents Analyzed (continued)

Analyzed Accidents Sequences (6 pages)

PHA acc seq #	Descriptor	Preliminary IROFS Identified
S.C.10	High concentrations of uranium enter the low-dose or high-dose waste collection tanks	• IROFS CS-14, Active Discharge Monitoring and Isolation • IROFS CS-15, Independent Active Discharge Monitoring and Isolation • IROFS CS-16, Sampling and Analysis of Uranium Mass or Concentration Prior to Discharge or Disposal • IROFS CS-17, Independent Sampling and Analysis of Uranium Concentration Prior to Discharge or Disposal • See Section 13.2.7.2
S.C.11	High concentrations of uranium in contactor solvent regeneration aqueous waste	• Bounded by S.C.04 and S.C.10
S.C.12	High concentrations of uranium in the LEU target material wash solution	• IROFS CS-04, Interaction Control Spacing Provided by Passively Designed Fixtures and Workstation Placement • IROFS CS-06, Pencil Tank, Vessel, or Piping Safe Geometry Confinement using the Diameter of Tanks, Vessels, or Piping • IROFS CS-07, Pencil Tank and Vessel Spacing Control Using Fixed Interaction Spacing of Individual Tanks or Vessels • See Section 13.2.7.2
S.C.13	High concentrations of uranium in the nitrous oxide scrubber	• IROFS CS-06, Pencil Tank, Vessel, or Piping Safe Geometry Confinement using the Diameter of Tanks, Vessels, or Piping • IROFS CS-16, Sampling and Analysis of Uranium Mass or Concentration Prior to Discharge or Disposal • IROFS CS-17, Independent Sampling and Analysis of Uranium Concentration Prior to Discharge or Disposal • See Section 13.2.7.2
S.C.14	High concentrations of uranium in the IX waste collection tanks effluent	• IROFS CS-16, Sampling and Analysis of Uranium Mass or Concentration Prior to Discharge or Disposal • IROFS CS-17, Independent Sampling and Analysis of Uranium Concentration Prior to Discharge or Disposal • See Section 13.2.7.2
S.C.15	High concentrations of uranium in the IX resin waste	• IROFS CS-06, Pencil Tank, Vessel, or Piping Safe Geometry Confinement using the Diameter of Tanks, Vessels, or Piping • IROFS CS-07, Pencil Tank and Vessel Spacing Control Using Fixed Interaction Spacing of Individual Tanks or Vessels • IROFS CS-16, Sampling and Analysis of Uranium Mass or Concentration Prior to Discharge or Disposal • IROFS CS-17, Independent Sampling and Analysis of Uranium Concentration Prior to Discharge or Disposal • See Section 13.2.7.2
S.C.17	High concentrations of uranium in the solid waste encapsulation process	• IROFS CS-16, Sampling and Analysis of Uranium Mass or Concentration Prior to Discharge or Disposal • IROFS CS-17, Independent Sampling and Analysis of Uranium Concentration Prior to Discharge or Disposal • IROFS CS-21, Visual Inspection of Accessible Surfaces for Foreign Debris • IROFS CS-22, Gram Estimator Survey of Accessible Surfaces for Gamma Activity • IROFS CS-23, Nondestructive Assay of Items with Inaccessible Surfaces • IROFS CS-24, Independent Nondestructive Assay of Items with Inaccessible Surfaces • IROFS CS-25, Target Housing Weighing Prior to Disposal • See Section 13.2.7.2
S.C.19	Failure of PEC – Component safe geometry dimension or safe volume	• IROFS CS-06, Pencil Tank, Vessel, or Piping Safe Geometry Confinement using the Diameter of Tanks, Vessels, or Piping • IROFS CS-07, Pencil Tank and Vessel Spacing Control Using Fixed Interaction Spacing of Individual Tanks or Vessels • IROFS CS-26, Processing Component Safe Volume Confinement • See Section 13.2.7.2
S.C.20	Failure of concentration limits	• No credible path leading to criticality identified or not credible by design

Other Accidents Analyzed (continued)

Analyzed Accidents Sequences (6 pages)

PHA acc seq #	Descriptor	Preliminary IROFS Identified
S.C.21	Target basket passive design control failure on fixed interaction spacing	• IROFS CS-02, Mass and Batch Handling Limits for Uranium Metal, Uranium Oxides, Targets, and Laboratory Sample Outside Process Systems • IROFS CS-03, Interaction Control Spacing Provided by Administrative Control • See Section 13.2.7.2
S.C.22	High concentration of uranium in the TCE evaporator residue	• IROFS CS-04, Interaction Control Spacing Provided by Passively Designed Fixtures and Workstation Placement • IROFS CS-06, Pencil Tank, Vessel, or Piping Safe Geometry Confinement Using the Diameter of Tanks, Vessels, or Piping • IROFS CS-07, Pencil Tank and Vessel Spacing Control Using Fixed Interaction Spacing of Individual Tanks or Vessels • IROFS CS-16, Sampling and Analysis of Uranium Mass or Concentration Prior to Discharge or Disposal • IROFS CS-17, Independent Sampling and Analysis of Uranium Concentration Prior to Discharge or Disposal • See Section 13.2.7.2
S.C.23	High concentration in the spent silicone oil waste	• IROFS CS-04, Interaction Control Spacing Provided by Passively Designed Fixtures and Workstation Placement • IROFS CS-05, Container Batch Volume Limit • IROFS CS-06, Pencil Tank, Vessel, or Piping Safe Geometry Confinement Using the Diameter of Tanks, Vessels, or Piping • IROFS CS-07, Pencil Tank and Vessel Spacing Control Using Fixed Interaction Spacing of Individual Tanks or Vessels • IROFS CS-16, Sampling and Analysis of Uranium Mass or Concentration Prior to Discharge or Disposal • IROFS CS-17, Independent Sampling and Analysis of Uranium Concentration Prior to Discharge or Disposal • See Section 13.2.7.2
S.C.24	High uranium content on HEPA filters and subsequent failure	• Bounded by S.C.17
S.C.27	Failure of administratively controlled container volume limits	• IROFS CS-03, Interaction Control Spacing Provided by Administrative Control • IROFS CS-04, Interaction Control Spacing Provided by Passively Designed Fixtures and Workstation Placement • IROFS CS-05, Container Batch Volume Limit • See Section 13.2.7.2
S.C.28	Crane load drop accidents	• IROFS FS-01, Enhanced Lift Procedure • IROFS FS-02, Overhead Cranes • See Section 13.2.7.2
S.F.01	Pyrophoric fire in uranium metal	• Event highly unlikely based on credible physical conditions
S.F.02	Accumulation and ignition of flammable gas in tanks or systems	• IROFS FS-03, Process Vessel Emergency Purge System • See Section 13.2.7.3
S.F.03	Hydrogen detonation in reduction furnace	• Judged highly unlikely based on credible physical conditions
S.F.04	Fire in reduction furnace	• Judged unlikely based on event frequency
S.F.05	Fire in a carbon retention bed	• IROFS FS-05, Exhaust Stack Height • See Section 13.2.7.3
S.F.06	Accumulation of flammable gas in ventilation system components	• Bounded by S.F.02
S.F.07	Fire in nitrate extraction system - combustible solvent with uranium	• Event unlikely with immediate or low consequences
S.F.08	General facility fire	• Information will be provided in the Operating License Application

Other Accidents Analyzed (continued)

Analyzed Accidents Sequences (6 pages)

PHA acc seq #	Descriptor	Preliminary IROFS Identified
S.F.09	Hydrogen explosion in the facility due to a leak from the hydrogen storage or distribution system	• Information will be provided in the Operating License Application
S.F.10	Combustible fire occurs in hot cell area	• Information will be provided in the Operating License Application
S.F.11	Detonation or deflagration of natural gas leak in steam generator room	• Information will be provided in the Operating License Application
S.N.01	Tornado impact on facility and SSCs important to safety	• Judged highly unlikely event based on return frequency
S.N.02	High straight-line winds impact the facility and SSCs important to safety	• Judged highly unlikely to result in structure failure
S.N.03	Heavy rain impact on facility and SSCs important to safety	• Bounded by S.N.06
S.N.04	Flooding impact to the facility and SSCs important to safety	• Judged highly unlikely event based on facility location above the 500-year flood plain
S.N.05	Seismic impact to the facility and SSCs important to safety	• Judged highly unlikely to result in structure failure • IROFS FS-04, Irradiated Target Cask Lifting Fixture • See Section 13.2.6.5
S.N.06	Heavy snowfall or ice buildup on facility and SSCs important to safety	• Judged highly unlikely to result in structure failure
S.M.01	Vehicle strikes SSC important to safety and causes damage or leads to an accident sequence of intermediate or high consequence	• Judged likely event with low consequence
S.M.02	Facility evacuation impacts on operations	• Judged likely event with low consequence
S.M.03	Localized flooding due to internal system leakage or fire suppression sprinkler activation	• IROFS CS-08, Floor and Sump Geometry Control of Slab Depth, Sump Diameter or Depth for Floor Spill Containment Berms • See Section 13.2.7.2
S.CS.01	Nitric acid fume release	• No IROFS currently identified

HEPA = high-efficiency particulate air.
IROFS = items relied on for safety.
IRU = iodine removal unit.
IX = ion exchange.
LEU = low-enriched uranium.
Mo = molybdenum.

PEC = passive engineered control.
PHA = preliminary hazards analysis.
SSC = structures, systems, and components.
TCE = trichloroethylene
U = uranium.
UN = uranyl nitrate.

ACCIDENTS WITH HAZARDOUS CHEMICALS

- Chemical Burns from Contaminated Solutions During Sample Analysis
  - Facility personnel will be required to follow strict protocols for sampling and analysis activities at RPF
  - Sampling locations, techniques, containers to be used, routes to take through RPF when transporting a sample, analysis procedures, reagents, analytical equipment requirements, and sample material disposal protocols will all be specified per procedures and/or work plans prepared and discussed prior to sampling or analytical activities
  - Operators and technicians will be required to wear personal protective equipment, specifically for eye and skin protection
  - Radiologically contaminated acidic and caustic solution samples will be handled in approved containers
    - Containers will be properly sealed when removed from sample locations and vent hoods during transport and/or storage
  - Sample containers will be opened only when securely located in an approved laboratory hood, with hood lowered for spray protection
    - Process will provide an additional layer of protection for eyes and skin (e.g., protective eyewear/face shield, laboratory coat or apron, anti-contamination chemical resistant gloves)

ACCIDENTS WITH HAZARDOUS CHEMICALS

- Nitric Acid Fume Release
  - Accident consists of a release of nitric acid fumes inside or outside of RPF originating from one of nitric acid storage tanks in the chemical storage and preparation room
  - As analyzed … A 1-hr release of bounding RPF inventory of 5,000 L of nitric acid was shown to cause a concentration of 1,200 parts per million (ppm) at controlled area fence line and 19.1 ppm at 434 m (1,425 ft) (nearest resident location) under dispersion conditions of moderate wind
  - Unmitigated exposure to a nearby worker would be much higher
    - AEGL-2, 60-minute (min) exposure limit for nitric acid is 24 ppm, which is high consequence to public
    - AEGL-3, 10-min exposure limit, is 170 ppm for a high consequence exposure to worker
  - Impact and consequences of a chemical release on RPF operations would require personnel to either evacuate facility or, under some circumstances, shelter in place depending on location of event
  - RPF will follow EPA and OSHA regulations for design, construction, and operation of chemical preparation and storage areas
    - Chemical handling procedures will be provided to operators to ensure safe handling of chemicals according to applicable regulatory requirements and consistent with applicable material safety data sheets

Chapter 13 Questions?

Advisory Committee on Reactor Safeguards
Subcommittee Meeting
Northwest Medical Isotopes Construction Permit Application

Integrated Safety Analysis Methodology

U.S. Nuclear Regulatory Commission

August 23, 2017

Introductions

- **Michael Balazik** - Project Manager, Research and Test Reactors Licensing Branch (PRLB), Division of Policy and Rulemaking (DPR), Office of Nuclear Reactor Regulation (NRR)
- **April Smith**- Reliability and Risk Analyst, Programmatic Oversight and Regional Support Branch, Division of Fuel Cycle Safety, Safeguards, and Environmental Review, Office of Nuclear Material Safety and Safeguards (NMSS)
- **Alexander Adams, Jr.** - Chief, PRLB, DPR, NRR
- **David Tiktinsky** - Senior Project Manager, Fuel Manufacturing Branch, Division of Fuel Cycle Safety, Safeguards, and Environmental Review, NMSS

Regulatory Basis and Acceptance Criteria

- Regulatory Requirements:
  - 10 CFR 50.34, “Contents of applications; technical information,” Paragraph (a), “Preliminary safety analysis report [PSAR]”
  - 10 CFR 50.35, “Issuance of Construction Permits”
  - 10 CFR 50.40, “Common standards.”
- Acceptance Criteria
  - NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria.”
  - Interim Staff Guidance (ISG) Augmenting NUREG-1537, Part 2 “Guidelines for Preparing and Reviewing Applications…for Licensing Radioisotope Production Facilities…”

Purpose of the Review

Context: ISG Augmenting NUREG-1537, Part 2 states that integrated safety analysis (ISA) methodologies, as described in 10 CFR Part 70 and NUREG-1520, are an acceptable way of demonstrating adequate safety for construction of a radioisotopes production facility.

Applicants are free to propose alternate methodologies, consequence and likelihood criteria, safety features, and methods of assuring the availability and reliability of the safety features.

Purpose: To determine whether there is reasonable assurance that NWMI has proposed an integrated safety analysis methodology (ISA) with elements that support the adequate identification of capabilities and features to prevent or mitigate potential accidents and protect the health and safety of the public and workers.

Review Procedures and Technical Evaluation

- To assess the adequacy of the ISA methodology, the staff performed a review of:
  - The ISA methodology presented in Chapter 13 of the NWMI PSAR
  - The ISA Summary
  - Information from other PSAR sections, such as Section 3.5

Review Procedures and Technical Evaluation

- The staff's evaluation included a review of the following:
    - The ISA Team
    - The definitions and application of the terms "not unlikely," "unlikely," "highly unlikely," "credible," and "not credible"
    - The description of the ISA methodology and demonstrated implementation in the ISA Summary

NWMI Radioisotope Production Facility Process Hazards

- Target fabrication process
- Target dissolution process
- Molybdenum recovery and purification process
- Uranium recovery and recycle process
- Waste handling system process
- Target disassembly
- Ventilation system
- Natural phenomena, man-made external events, and other facility operations

ISA Methodology

- Perform hazards analysis (structured what-if, what-if, HAZOP)
- Qualitatively assess likelihood, consequences, and risk category
- Perform quantitative risk analysis (QRA) on indeterminate, intermediate, and high risk events
- Identify accident sequences for intermediate and high risk events based on QRA results
- Determine IROFS and boundary definition packages
- Incorporate into design and documentation

ISA Methodology

Table A-1 Consequence Severity Categories Based on 10 CFR 70.61

	Workers	**Offsite Public**	**Environment**
Category 3 **High Consequence**	*RD > 1 sievert (Sv) (100 rem) **CD = endanger life	RD > 0.25 Sv (25 rem) 30 milligrams (mg) sol U intake CD = long-lasting health effects	
Category 2 **Intermediate Consequence**	0.25 Sv (25 rem) < RD ≤ 1 Sv (100 rem) CD = long-lasting health effects	0.05 Sv (5 rem) < RD ≤ 0.25 Sv (25 rem) CD = mild transient health effects	Radioactive release > 5,000 x Table 2 of 10 CFR Part 20, Appendix B
Category 1 **Low Consequence**	Accidents with lower radiological and chemical exposures than those above in this column	Accidents with lower radiological and chemical exposures than those above in this column	Radioactive releases producing lower effects than those referenced above in this column

* RD = Radiological Dose

** CD = Chemical Dose

Source: NUREG-1520, “Standard Review Plan for Fuel Cycle Facilities License Applications”

ISA Methodology

Table A-2 Likelihood Categories Based on 10 CFR 70.61

	Qualitative Description
Likelihood Category 1	Consequence Category 3 accidents must be "highly unlikely."
Likelihood Category 2	Consequence Category 2 accidents must be "unlikely."
Likelihood Category 3	Consequence Category 1 accidents may be "not unlikely."

Source: NUREG-1520, "Standard Review Plan for Fuel Cycle Facilities License Applications"

ISA Methodology

Table A-3 Risk Matrix with Risk Index Values

Severity of Consequences	**Likelihood of Occurrence**		
	Likelihood Category 1 Highly Unlikely (1)	Likelihood Category 2 Unlikely (2)	Likelihood Category 3 Not Unlikely (3)
Consequence Category 3 High (3)	Acceptable Risk 3	Unacceptable Risk 6	Unacceptable Risk 9
Consequence Category 2 Intermediate (2)	Acceptable Risk 2	Acceptable Risk 4	Unacceptable Risk 6
Consequence Category 1 Low (1)	Acceptable Risk 1	Acceptable Risk 2	Acceptable Risk 3

Source: NUREG-1520, “Standard Review Plan for Fuel Cycle Facilities License Applications”

Review areas deferred to FSAR

- Demonstration of ISA team qualification and training to appropriately assess event frequencies and consequences

- Demonstration of appropriate hazard analysis based on the associated hazard

- Demonstration of compliance with performance requirements
  - Adequate technical basis established for likelihoods and consequences
  - Appropriate application of the terms for likelihood and credibility
  - Review of IROFS boundary packages
  - IROFS established prevent or mitigate, as intended
  - Adequate management measures established to support availability and reliability of IROFS

Evaluation Conclusion

- The applicant provided reasonable assurance that its proposed integrated safety analysis methodology contains the elements that support the adequate identification of capabilities and features to prevent or mitigate potential accidents and protect the health and safety of the public and workers.

- Further technical or design information may be reasonably left for later consideration in the FSAR.

Supplemental Slides

Information to be Reviewed in the FSAR

- Detailed review of quantitative risk analyses
  - Review assumptions and inputs requiring verification (consistency in and reasonableness of credibility, failure rates, frequencies, and consequences)
  - Perform vertical slice reviews of specific systems and accident sequences, e.g. spray release of dissolver product solution
    - Intermediate consequence to the public (unmitigated 300 mrem to the nearest resident, mitigated 30 mrem)
    - Review assumptions critical to concluding exhaust system will mitigate as described

Information to be Reviewed in the FSAR

- Detailed review of high consequence accident sequences with no IROFS based on low frequency events
  - Review for implicit assumptions of equipment or structural survivability
  - Review for appropriate assumptions of uncertainty in low frequency natural phenomena events, e.g. tornado given a tornado impact on SSCs important to safety located outside the main facility could result in high consequences

Advisory Committee on Reactor Safeguards
Subcommittee Meeting
Northwest Medical Isotopes Construction Permit Application

Chapter 13
Radioisotope Production Facility Accident Analysis

U.S. Nuclear Regulatory Commission

August 23, 2017

Introductions

- **Michael Balazik** - Project Manager, Research and Test Reactors Licensing Branch (PRLB), Division of Policy and Rulemaking (DPR), Office of Nuclear Reactor Regulation (NRR)
- **James Hammelman** - Senior Chemical Engineer, Fuel Manufacturing Branch (FMB), Division of Fuel Cycle Safety, Safeguards, and Environmental Review Office of Nuclear, Material Safety and Safeguards (NMSS)
- **Alexander Adams, Jr.** - Chief, PRLB, DPR, NRR
- **David Tiktinsky** - Senior Project Manager, FMB, Division of Fuel Cycle Safety, Safeguards, and Environmental Review, NMSS
- **John Atchison** - Technical Reviewer, Information Systems Laboratories Inc. (ISL)

Regulatory Basis and Acceptance Criteria

- Regulatory Requirements:
  - 10 CFR 50.34, “Contents of applications; technical information,” paragraph (a), “Preliminary safety analysis report.”
  - 10 CFR 50.35, “Issuance of construction permits.”
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- Acceptance Criteria:
  - NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria.”
  - Interim Staff Guidance Augmenting NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications…for Licensing Radioisotope Production Facilities…,”

Accident Analysis

Identify and analyze the accident scenarios that represent the range of credible accidents in the NWMI facility using an Integrated Safety Assessment (ISA) methodology.

Areas of Review

- NWMI PSAR Chapter 13, Rev 1, “Radioisotope Production Facility (RPF) Accident Analysis”.
  - Section 13.1, “Accident Analysis Methodology and Preliminary Hazards Analysis”
  - Section 13.2, “Analysis of Accidents with Radiological and Criticality Safety Consequences”
  - Section 13.3, “Analysis of Accidents with Hazardous Chemicals”
- Objective of the staff review is to determine with reasonable assurance that the proposed RPF design at the construction permit stage has adequate preliminary IROFS to prevent or mitigate credible accidents with intermediate or high consequences.

Staff review of Section 13.2, “Analysis of Accidents with Radiological and Criticality Safety Consequences”

- The staff evaluated the technical information presented in Section 13.2 of the NWMI PSAR, Rev 2, as supplemented by responses to requests for additional information (RAIs), to assess the sufficiency of the NWMI accident analysis for the issuance of a construction permit.
- The staff considered the applicant’s selection and analysis of credible accidents, identification of radiological accident source terms, calculation of unmitigated radiological doses, and preliminary IROFS.

Summary of Application

- PSAR Section 13.2 presents the analysis summary and results of credible RPF accidents involving operations of irradiated target processing, target material recycling, and radioactive waste handling.
- NWMI assumes postulated criticality accidents are high consequence events.
- NWMI presents preliminary quantitative estimates for dose consequences from the accident analyses to the public. Updated quantitative safety consequences will be provide in the operating license application (OLA) based on the final design.
- NWMI has presented qualitative worker consequence estimates in the PSAR. The PSAR states that quantitative worker safety estimates will be performed as the design matures and will be presented in the FSAR.

Summary of Application (continued)

- PSAR Section 13.2.2 discusses spill and spray accidents resulting in radiological consequences or criticality.
- PSAR Section 13.2.3 discusses dissolver off-gas accidents resulting in radiological consequences.
- PSAR Section 13.2.4 discusses leak into auxiliary system accidents resulting in radiological consequences or criticality.
- PSAR Section 13.2.5 discusses loss of electrical power accidents.

Summary of Application (continued)

- NWMI PSAR Section 13.2.6 discusses the evaluation of possible accidents initiated by natural phenomena events.
- NWMI PSAR Section 13.2.7 presents a summarizes other possible accident scenarios identified in the Preliminary Hazards Analysis (PHA) that require IROFS.

Staff Review of “Spills and Sprays” Accident Analyses

- PSAR Section 13.2.2 provides a description of the accident analysis category “Liquid Spills and Sprays”. The accident scenario is identified as a liquid leak/spray accident involving the dissolver product solution or the Uranium Separation feed in the uranium recovery and recycle systems. The dissolver product liquid process stream is characterized using the bounding radionuclide liquid waste stream concentrations.

- Accident scenarios: A process line or vessel ruptures or leaks, spraying (or emptying its contents) into the hot cell. Hot cell atmosphere exhausts to the environment with no filters active.

Staff Review of "Spill and Sprays" Accident Analyses (continued)

- Accident likelihood: not unlikely
- Unmitigated radiological consequences exposure for accident:
  - Worker: High consequence
  - Public: To be provided in FSAR

Staff Review of “Spill and Sprays” Accident Analyses (continued)

- Preliminary IROFS selected to prevent or mitigate the spill or spray leak accident radiological doses:
  - RS-01, Hot cell liquid confinement boundary
  - RS-03, Hot cell secondary confinement boundary (Zone 1 exhaust negative pressure, HEPA filters, HEGA filters, exhaust stack height)
  - RS-04, Hot cell shielding boundary
- Preliminary IROFS selected to prevent the spill or spray leak accident criticality:
  - CS-07, Pencil tanks and vessel spacing control
  - CS-08, Floor and sump geometry control
  - CS-09, Double wall piping

Staff Review of “Target Dissolver Off-gas” Accident Analyses

- PSAR Section 13.2.3 provides a description of the accident analysis category “Target Dissolver Off-gas Accidents”. The accident scenario is identified as a process upset resulting in the loss of efficiency of radioiodine removal in the target dissolver offgas system.

- Accident likelihood: not unlikely

- Unmitigated radiological consequences exposure for accident:
  - Worker: To be provided in FSAR
  - Public: Intermediate consequence

Staff Review of "Target Dissolver Off-gas" Accident Analyses (continued)

- Preliminary IROFS selected to prevent or mitigate the target off-gas accident radiological doses:
  - RS-03, Hot cell secondary confinement boundary (Zone 1 exhaust negative pressure, HEPA filters, HEGA filters, exhaust stack height)
  - RS-09, Primary off-gas relief system

Staff Review of “Leaks into Auxiliary Systems” Accident Analyses

- PSAR Section 13.2.4 provides a description of the accident analysis category “Leaks into Auxiliary Systems”. The accident scenario is identified as a liquid solution leak into secondary containment (e.g., cooling water jackets) which could cause radiological exposures or a criticality event.
- Accident likelihood: not unlikely
- Unmitigated radiological consequences for accident:
  - Worker: high consequence
  - Public: not applicable, no release to the environment

Staff Review of “Leaks into Auxiliary Systems” Accident Analyses (continued)

- Preliminary IROFS selected to prevent or mitigate the leaks into an auxiliary system accident radiological doses:
  - RS-04, Hot cell shielding boundary

- Preliminary IROFS selected to prevent the leak into an auxiliary system accidental criticality:
  - CS-06, Pencil tanks and vessel spacing control
  - CS-10, Closed safe geometry heating or cooling loop
  - CS-27, Closed heating or cooling loop
  - CS-20, Evaporator or concentrator condensate monitoring
  - CS-18, Backflow prevention device
  - CS-19, Safe geometry day tanks

Staff Review of “Loss of Power” Accident Analyses

- PSAR Section 13.2.5 provides a detailed description of the accident analysis category “Loss of Power”.
- Unmitigated accident likelihood: not unlikely
- IROFS selected to prevent or mitigate the loss of power accident:
  - No additional IROFS were identified specific to this event other than maintaining IROFS identified in PSAR Section 13.2.5.3

Staff Review of “Natural Phenomena” Accident Analyses

- PSAR Section 13.2.6 provides a description of the accident analysis category “Natural Phenomena Events”. The RPF is designed to withstand effects of natural phenomena events, with design descriptions provided in NWMI PSAR Chapters 2 and 3.

- Natural phenomena events evaluated include:
  - Tornado, high straight line winds, heavy rain, flooding, seismic, heavy snowfall or ice buildup

- IROFS selected to prevent/mitigate natural phenomena events:
  - Seismic: FS-04, Irradiated target cask lifting fixture (prevents cask tipping

- Review of high consequence accidents sequences with no IROFS based on low frequency events will be reviewed in the FSAR

Staff Review of “Other Accidents Analyzed”

- In PSAR Section 13.2.7, NMWI identified its analyzed accident sequences and preliminary IROFS including those evaluated in other sections of PSAR 13.2

- IROFS were presented to prevent or mitigate intermediate or high consequence events or to prevent criticality

Staff Analysis Findings of Accidents with Radiological and Criticality Safety Consequences

- The staff evaluated the sufficiency of the accident analysis and selection of preliminary IROFS for the RPF as described in NWMI PSAR 13.2, “Analysis of Accidents with Radiological and Criticality Safety Consequences,” by reviewing the preliminary accident analysis scenarios, accident analysis results, and the IROFS selected to prevent and/or mitigate the possible accidents.

- The applicant will update the worker and public quantitative safety consequences and likelihoods in the OLA in the FSAR.

Staff Analysis Findings of Accidents with Radiological and Criticality Safety Consequences (continued)

- The staff has determined that the summary description of the NWMI RPF accident analysis and IROFS selection documented in PSAR Section 13.2 demonstrates an adequate design basis for a preliminary design.

- The staff concludes that the preliminary accident analysis of the RPF is sufficient for issuance of a CP. Additionally, the subsequent selection of IROFS and management measures should, with reasonable assurance, protect the health and safety of the workers and public.

Chemical Accident Analyses

- Section 13.3, “Analysis of Accidents with Hazardous Chemicals”

- The staff performed an evaluation of the technical information presented in the NWMI PSAR, Rev 1, as supplemented by responses to requests for additional information (RAIs), to assess the sufficiency of the NWMI accident analysis for the issuance of a construction permit.

- The purpose of the review was to determine whether the Criteria of 10 CFR 50.35 are met for chemical hazards.

Staff Chemical Safety Review Approach

- Review design criteria and performance objective
- Review the process, equipment and facility design
- Review accident analysis/ISA and identified safety features for the protection of workers and public (energetic hazards, toxic hazards)
- Evaluate adequacy of Engineered Safety Features
- Evaluate need for additional information/analysis for the FSAR and applicant’s plan to develop such information

Design Criteria and Performance Objectives

- Proposed design standards – PSAR Chapter 3
  - ASTM standards for hot cells
  - Compliance with the performance requirements in 10 CFR 70.61
    - High consequence events highly unlikely
    - Intermediate consequence events unlikely
- Design Standards and performance requirements are acceptable

Staff Review of Chemical Accident Analyses

- Examined all accident sequences in PSAR/ISA summary focusing on those related to chemical safety

- PSAR/ISAs presented multiple accident sequences related to chemical safety
  - Accidents involving energetic reactions
  - Accidents involving release of toxic material

- Checked PSAR consequence estimates for accidents with a chemical safety component

Staff Review of Chemical Accident Analyses

- Information for FSAR Review
  - Re-examine chemical safety for final design
  - Evaluate analysis of energetic hazards including the results of planned R&D effort
  - Evaluate preventive Engineered Safety Features/IROFS

Chemical Accident Analysis Findings and Conclusions

- The description of the design, including principal criteria is adequate.
- The description identifies major features which will protect the heath and safety of the public from chemical hazards associated with the current design.
- NWMI statements allow the staff to conclude that further information related to chemical hazards which can be reasonable left to the FSAR will be supplied in the FSAR.
- Features that require R&D have been described by the applicant who will conduct an R&D program to resolve the safety questions for the FSAR.
- There is reasonable assurance that chemical hazard safety questions can be resolved and that the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public.

Evaluation Findings and Conclusions

- Accordingly, NWMI has met the following requirements of 10 CFR 50.35 for issuance of a construction permit, with respect to the chemical, radiological and criticality safety:
    1) NWMI has analyzed a set of accidents that should be representative of the possible range of events that may occur in an operating production facility and identified the selection of preventative and mitigating preliminary IROFS.
    2) Further detailed technical, design, or analysis information may be reasonably left for later consideration in the FSAR to support operation of the facility.
    3) Safety features which require R&D have been described and the applicant identified and will conduct an R&D program to resolve safety questions.
    4) There is reasonable assurance that the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public and workers.